CONTINENTAL ELECTRIC LIGHT CENTRAL STATIONS.

WITH

NOTES ON THE METHODS IN ACTUAL PRACTICE

FOR

DISTRIBUTING ELECTRICITY IN TOWNS.

COMPILED IN PART FROM THE REPORTS MADE FOR THE CONGRESS OF THE GERMAN MUNICIPAL AUTHORITIES, ON THE OCCASION OF THEIR VISIT TO THE INTERNATIONAL ELECTRICAL EXHIBITION AT FRANKFORT, 26TH–29TH AUGUST, 1891.

BY

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PREFACE.

In publishing this description of Continental Electric Light Central Stations the writer had a twofold object, first, to enable the members of lighting committees and others taking up the question of the introduction of electricity to obtain a rapid survey of what has been done abroad, both on a large and small scale; and, secondly, to enable electrical engineers to follow those arrangements for distributing electricity which differ from the usual English practice.

After visiting the Frankfort Electrical Exhibition the greatest sceptic ought to have been convinced that, however forward the art of electric lighting may be here, our foreign neighbours are quite up to date, and, quoting the words of Professor Forbes, "That to ensure the best success of electric lighting schemes now on hand we should bury our pride a little and try to obtain the experience of foreign countries."

The idea of putting forward a description of the latest electrical installations is due to the Committee of the recent Frankfort Exhibition, who asked the principal German electrical firms and other users of electric light to explain the systems adopted; these reports were combined in a work entitled "Die Versorgung von Städten mit Elektrischem Strom," which was presented to the members of the congress of municipal authorities on the occasion of their visit to Frankfort. With the permission of the contributors, the writer availed himself of much of the information, also has republished many of the working drawings, photographs and sketches of the electrical distributing arrangements. To this is added a description of some central stations which he has visited during the past two years, the various installations having been grouped under two heads—Part I., High Pressure; Part II., Low Pressure.

As the local authorities of many small towns have taken great interest in the electric light, it was thought desirable to include minor installations as well as those larger and more important; it is interesting to note that owing to the use of water power the working cost of the former is, as a rule, very low.

Ten years ago the question of the so-called division of the electric light had just been settled, and it was through the practically simultaneous announcement of the perfected Edison light in the United States and the Swan lamp here that the problem of applying the electric current to domestic illumination was solved at last. The past year has also witnessed in the Lauffen experiments another development which, from a monetary point of view, will probably in the next decade show greater advantages than the invention of the glow lamp has in the past. Although there

are no great waterfalls or rapid streams in this country, what is to prevent the utilization of the coal at the pit's mouth, by converting it into electrical energy which could be distributed throughout our manufacturing districts in a far more economical way than with the present mode of transport by rail and road?

In Part III. the pioneer enterprise of transmitting the power of the waterfalls at Lauffen as electrical energy to Frankfort is briefly described. The report of the jury of experts, which has been recently published, shows an undoubtedly high efficiency which will disappoint the prophets of evil. Notes on the Distribution, of Electricity compared with Gas are added; also some remarks on the present position of Gas Companies, and the desirability of their following the example of many American companies who have found it most profitable to take up the business of supplying electricity.

As it has been quite impossible to avoid using technical expressions, an Explanation of Technical Terms is added, which it is hoped will be of assistance to non-professional readers.

My thanks are particularly due to those Continental engineers who have not only allowed me to make use of their reports, but have, in many instances, furnished copies of their working drawings, which I am thus able to reproduce. The Institution of Electrical Engineers, Professor Forbes, and the editors of the "Engineer," "Electrical Review," and "Electrician," have also given me facilities which I gratefully acknowledge.

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7, Carteret Street, Westminster.
January, 1892.

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PART I.

HIGH-PRESSURE DISTRIBUTION BY ALTERNATING CURRENTS AND TRANSFORMERS.

CONTINENTAL ELECTRIC LIGHTING STATIONS.

THE ZIPERNOWSKY-DÉRI-BLÁTHY SYSTEM.

DISTRIBUTION BY MEANS OF HIGH-TENSION CURRENTS AND TRANSFORMERS, WITH DESCRIPTIONS OF THE CENTRAL STATIONS OF ROME, TIVOLI, VENICE, LEGHORN, INNSBRUCK, MARIENBAD, KARLSBAD, VIENNA, FIUME, VALRÉAS AND DIEU-LE-FIT.

BY GANZ & CO., BUDAPEST.

FOR the successful application of the electric current to large rambling districts, a system must be employed which does not need an excessively high expenditure on mains, nor at the same time involve extreme losses in the supply cables. Electrical projects are specially suitable for utilizing power already at hand, as undoubtedly current can be transmitted to any distance, although a great drawback, namely, the excessive cost of mains, in practice fixes the limit.

With lamps in parallel, the size of the mains is directly proportional to their number, though also depending on the distance from the generator to the lamp farthest away. The first consideration when designing an electric light station is the distribution of the current, although the installation expenses of the station must not be neglected; but the system employed must be such as to reduce this cost as much as possible, whilst it should allow both for an increase in the number of lamps to be maintained and also provide current available for other purposes besides lighting. The best way of minimizing the cost of mains is to place the lamps in series, as shown by Fig. 1; this is undoubtedly the cheapest plan, and with arc lamps the system is practical, but for glow lamps it offers great difficulties. There is at the present time, as far as we know, no higher voltage used than 5000, but even this high potential would only feed fifty lamps requiring a hundred volts each; besides, if one lamp goes out, the whole of them would be extinguished, unless provided with automatic switches. These and many other considerations render the

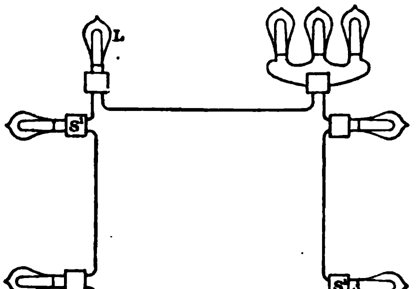


FIG. 1.—SERIES SYSTEM.

series system unsuitable for glow lamps. The problem of the economical supply of current was attempted to be solved—more especially for street lighting—by means ot the series-parallel system, in which groups of lamps in series are connected to the mains, as, for example, in the Temesvar installation;* but this arrangement still possesses the disadvantages of the series system, and the high potential used renders it dangerous for house lighting. Actual facts prove the unsuitability of the series system for glow lamps, and attempts have been made to combine the several advantages of the two systems in various ways, but without giving a perfectly satisfactory result. The best method of transmitting electricity to great distances is doubtless by use of the transformers; but before going on to the description of this system, we will briefly refer to the properties of these instruments.

Transformers generate current by induction, not by the movement of magnets or coils, but by changes in the magnetic condition of the iron, which is stationary. For the purpose required, it is so arranged that a small current at high potential will induce in the secondary winding a larger current at less potential. The principle of the transformer has for years been employed in the Ruhmkorff coil; and for the various applications of the electric current, where high potentials are unsuitable, the transformer has now for a considerable time proved a solution of the problem.

In 1882, Gaulard and Gibbs took out a patent for a method including all the essential points of previous patents; in April, 1883, their system was publicly tried at the Royal Aquarium, London. The apparatus, which they called "secondary generators," consisted of four bobbins wound with wire, which by means of a switch could be put in parallel or series; the current was regulated by means of the coils, and also by an iron core inside them. In 1884, Gaulard and Gibbs experimentally tried their transformers at Turin, attracting considerable attention.

The principles above referred to underlie the system which the electricians of Ganz & Co.—Messrs. Zipernowsky, Déri and Bláthy—have developed, although the transformers used differ considerably from Gaulard's, and give as a result great capacity for size, high efficiency, with durability and simplicity.

If two or more transformers are put in series and supplied by one generator which gives a constant current to all the primaries, then each secondary winding forms a source of power independent of the rest; and if lamps are put in parallel in these circuits, their number must always remain the same, as switching a lamp in or out disturbs the remainder. Any regulating apparatus to make this possible also interferes with the working of the rest of the circuit. From this it is evident that the series method of working is only suitable for town lighting, where the demand is constant, for it is evident that the proper working of the lamps of one consumer depends upon whether those of another are alight or not.

The Zipernowsky-Déri system provides for complete independence, the transformers giving constant potential. These transformers are connected in parallel, either singly or in groups, on to the mains, which are supplied at constant potential, the current in the secondary circuits being proportional to the number of lamps

* *See* page 57.

worked. Fig. 2 shows the arrangement: D, alternating current dynamo; E, exciter, continuous current; L, L^1, the line; M, M, the secondary winding of the transformers; T, T, the primary; S^1, S^2, the wires in which the lamps are fixed.

An experimental installation on this system was tried at the Vienna Industrial Museum, in the beginning of 1885. The system was first used practically by the firm of Ganz & Co., at the Budapest National Exhibition of 1885; 1200 glow lamps were lighted in the pavilions and restaurants, which were about 1400 yards from the central station, and worked for the whole time of the Exhibition (from May 1 to Oct. 30, 1885) with very satisfactory results. Transformers were also used in the same year at the Antwerp and London (Inventions) Exhibitions.

The switching in of alternate-current dynamos in parallel—which had been doubted by many prominent electricians—was also accomplished, greatly increasing the suitability of the system for central stations; and an instrument for regulating the current was also constructed about this time, by Ganz. Large numbers of regulators are now used. The introduction of alternate-current motors made it possible for central stations to supply power by means of transformers, many examples of which are working at the present time, as for instance:—

At Fiume, where an elevator is worked by alternate-current motors of 120 H.P.; at the central stations of Alzam Maggiore, Innsbruck, Grenoble and Vienna (Neustadt); and the works of Schneider & Co., in Creusot; also at the Frankfort Exhibition, where a great number of these motors were shown in operation.

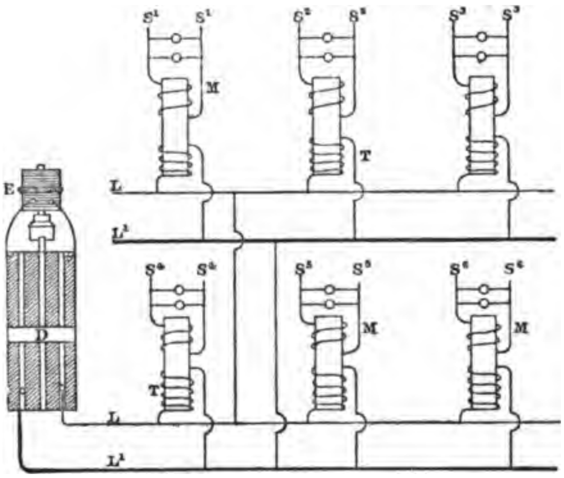


FIG. 2.—TRANSFORMERS IN PARALLEL.

That the expectations for the Zipernowsky system have been realized is shown by its rapid extension to all parts of the world. The firm and their licensees in various countries have erected nearly a hundred central stations, many of them large undertakings, and giving very satisfactory results. Out of several which are described, two of the most recent construction are that at Tivoli near Rome and the station at Karlsbad.

The Tivoli station supplies current to feed the mains, about 19 miles (30 kilometres) distant, which have for a considerable time been laid in Rome, where the central station is insufficient to meet the demand.

The Karlsbad station is noticeable for the fact that the mains are laid throughout the whole town, supplying glow lamps and arcs for both public and private lighting, almost exactly in the same way as a gas service.

THE TIVOLI CENTRAL STATION.

The motive power for this station is obtained, to the extent of about 2000 H.P., from a waterfall giving about 825 gallons of water per second, at a height of 160 feet. The machinery-house and the fall which is utilized are shown by Fig. 3. Six turbines of 300 H.P. each are used, coupled directly to alternating-current dynamos, each of 230,000 watts capacity, driving at a speed of 170 revolutions per minute. There are also three continuous-current machines, driven directly by separate turbines at a speed of 375 revolutions, used for exciting the alternators. A ground plan of the station is shown in Plate I., scale 1 in 90.

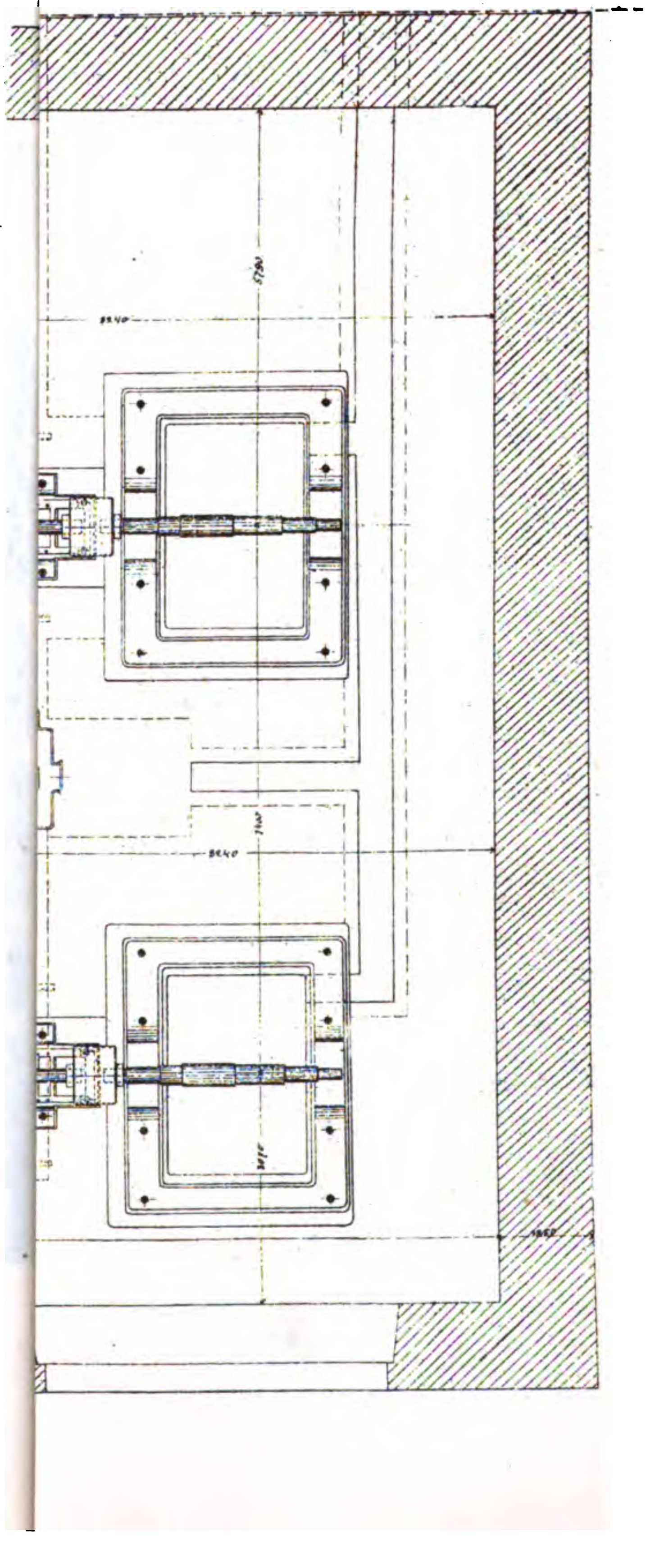
The dynamos at full load give a current at 5000 volts, which is conducted from Tivoli to Rome, a distance of about 19 miles, by means of bare copper wires, 100 sq. mm. (·16 sq. in.) in section, the fall of potential being twenty per cent. At the boundary of the town of Rome, near the Porta Pia, there is a distributing tower with transformers for reducing the 5000 volts to 2000 volts, at which potential the network is supplied, being again transformed to 100 volts at the consumer's premises. A part of the current from the Tivoli falls will be used for street lighting by having forty lamps in series, dispensing with the second transformer.

ROME.

This important enterprise dates from the autumn of 1886. From the very first, at this central station, a new departure in electric lighting was inaugurated, both with regard to the dimensions and disposition of the plant; the arrangement, however, had been exhibited the previous year, by the contractors, at the Electrical Exhibition, Budapest. The station, which is now equal to a supply of 24,000 sixteen-candle-power lamps, has gradually increased. The first order was for two alternating-current machines of 80,000 watts (2000 volts × 40 amperes), each of which was coupled direct to a horizontal high-pressure engine, running at a speed of 250 revolutions per minute. After a short time, these dynamos were found to be taxed to their full capacity, and a second order was given to Messrs. Ganz, for another double plant of 320,000 watts (2000 volts × 160 amperes), each dynamo being driven direct, as in the smaller set, but requiring engines of 500 H.P.

The general arrangement of the large steam dynamos is shown in the illustrations, Fig. 4 (125 H.P. engines and dynamos), Fig. 5 (600 H.P. engines and dynamos), Fig. 6 (general view). The engines are compound, and drive the dynamos by means of a disc fastened to the main shaft; no fly-wheel is necessary on account of the large diameter of the revolving armature. The low speed of 125 revolutions per minute is found to be quite practicable; and, on visiting the station, an engineer is struck with the great advantage of slow direct driving, and mentally compares the quiet working of these colossi with the too often noisy quick-speed engines or

Plate I.



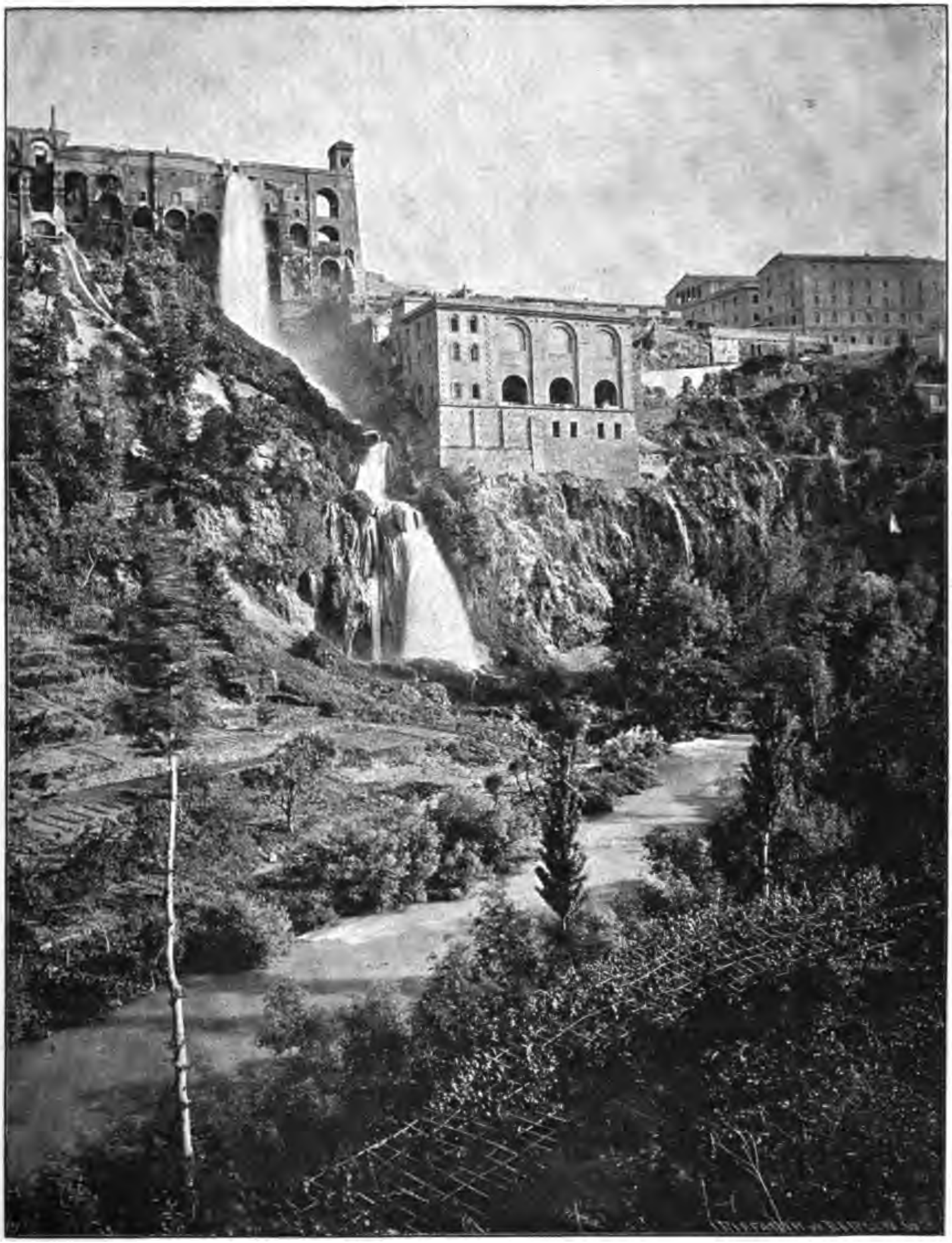


FIG. 3.—TIVOLI CENTRAL STATION.

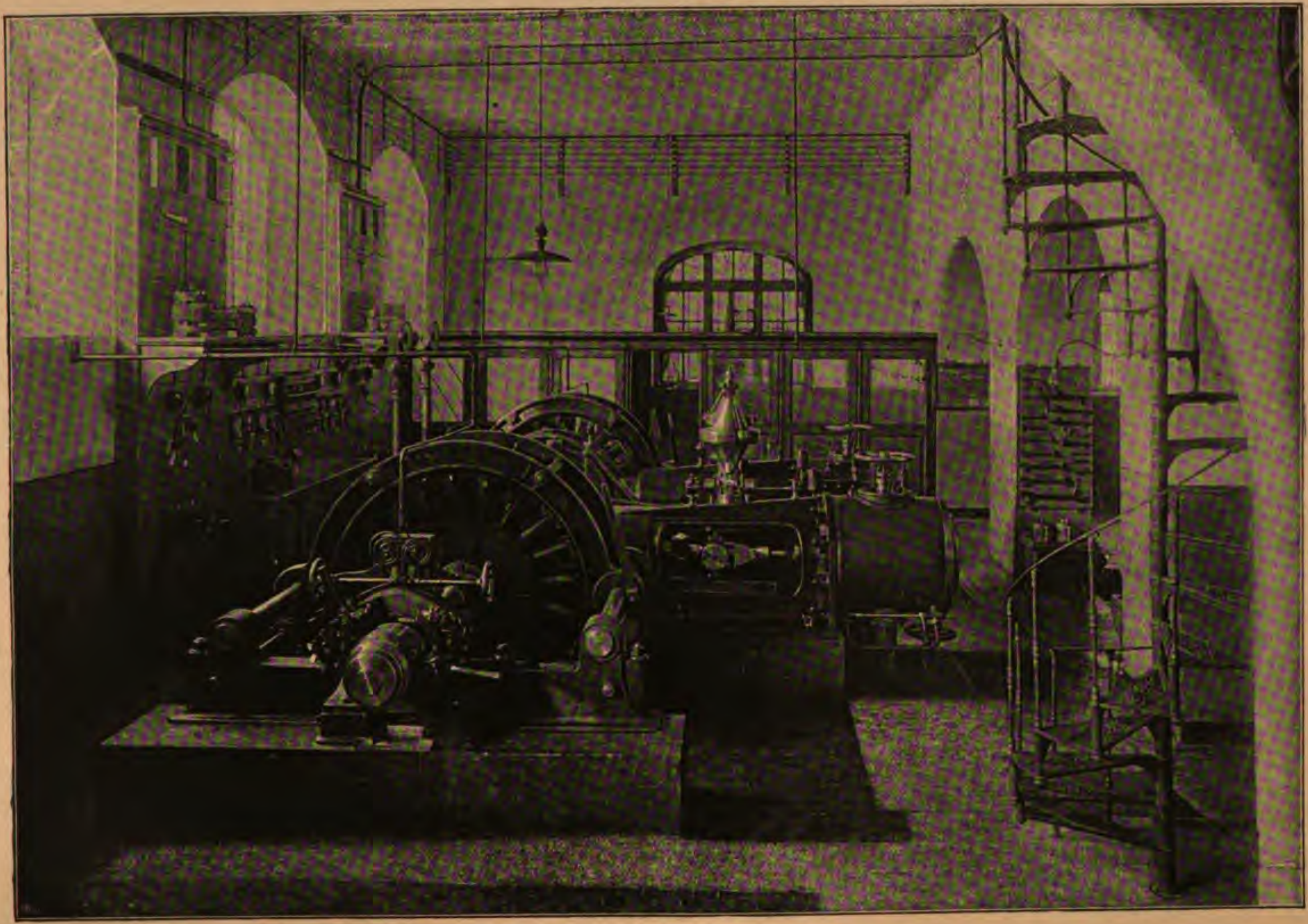


FIG. 4.—125 H.P. ENGINES AND DYNAMOS, ROME.

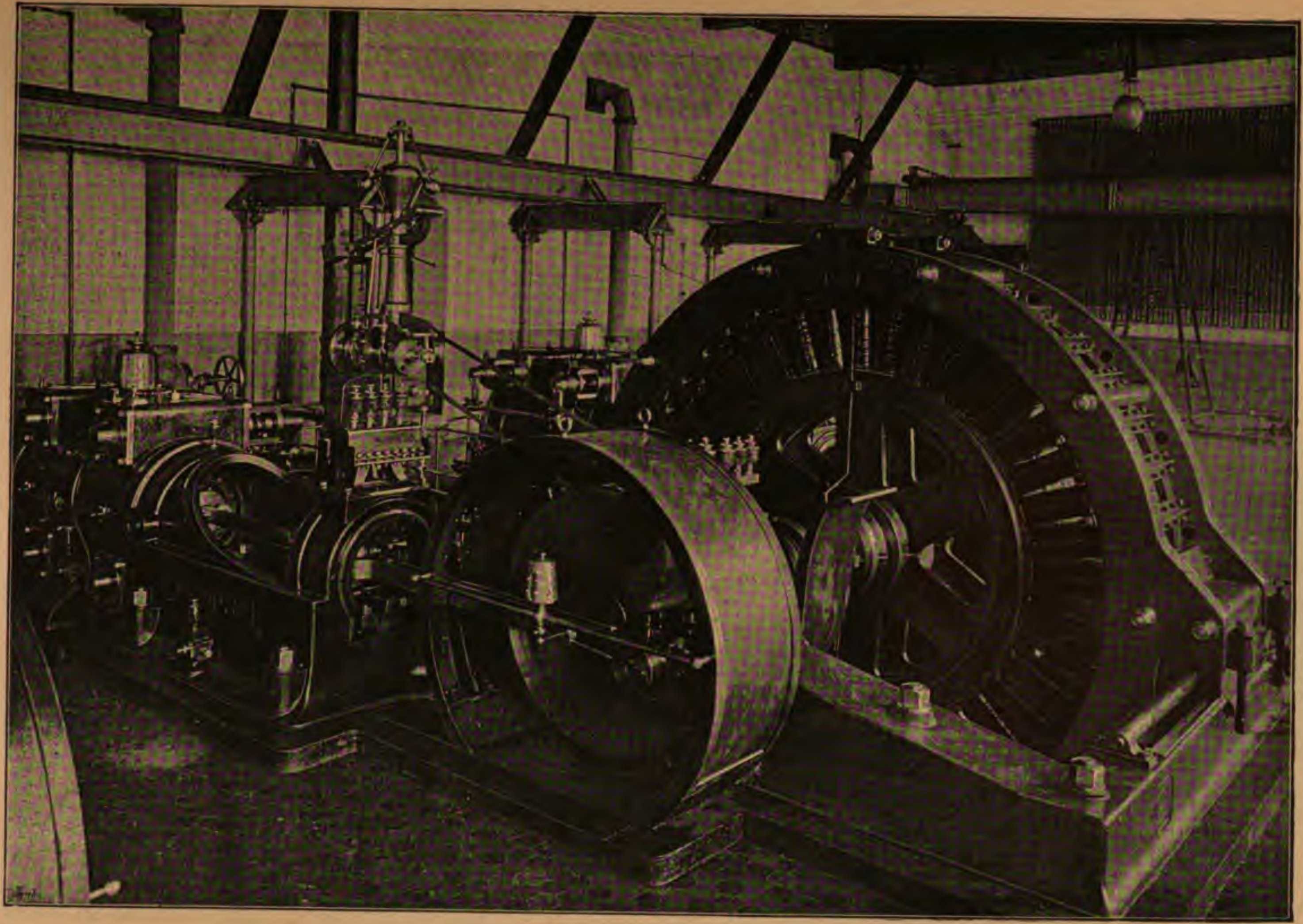


FIG. 5.—600 H.P. ENGINES AND DYNAMOS, ROME.

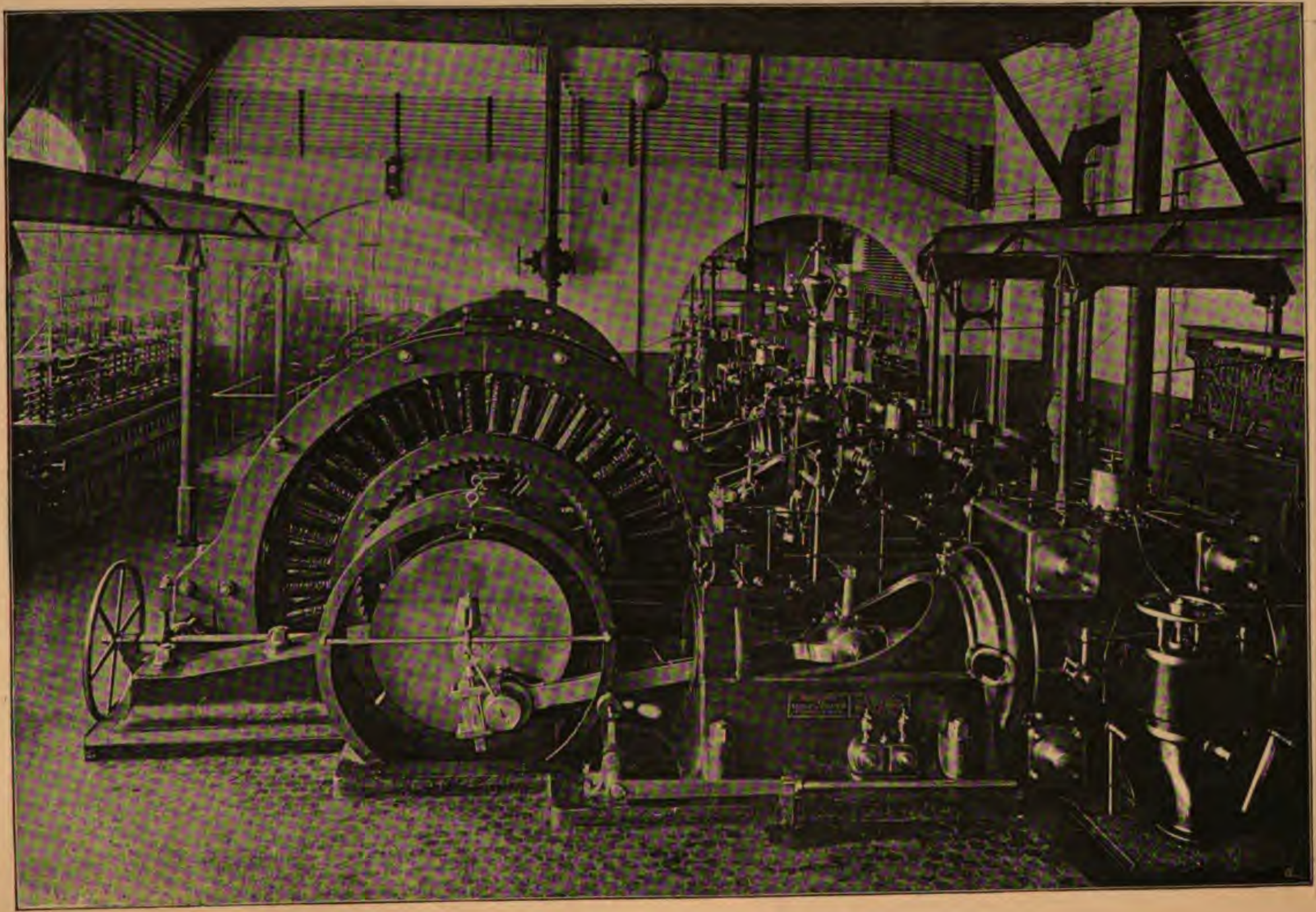
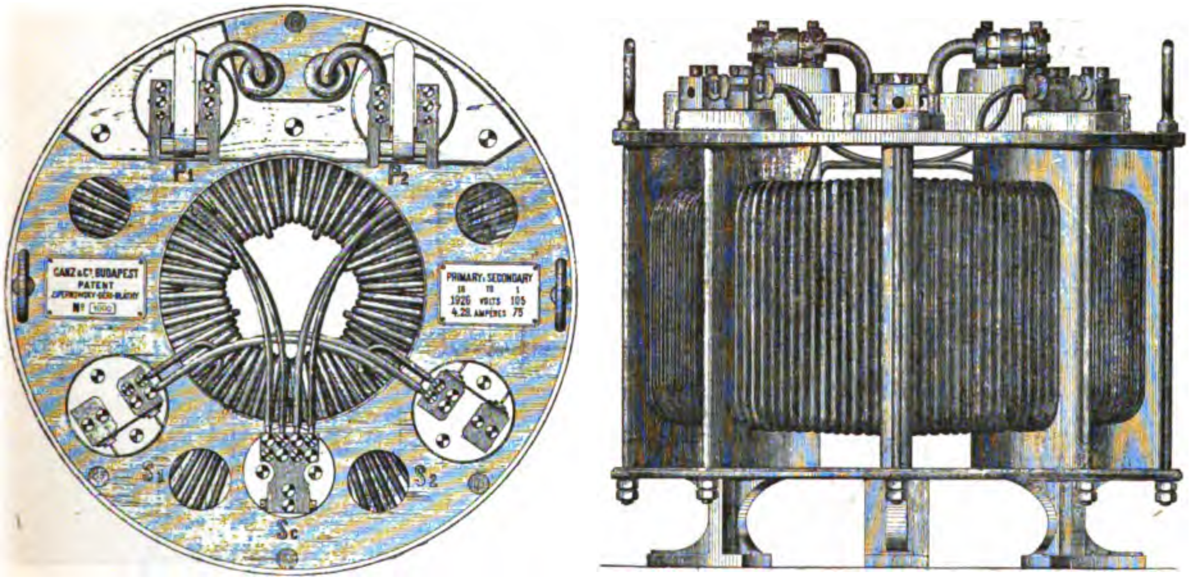


FIG. 6—GENERAL VIEW OF CENTRAL STATION.

flapping belt-driven dynamos he has been used to at home. The exciting continuous-current machines, of which there are four, arc erected in a separate part of the station. Each dynamo is directly driven by its own steam engine, in the same way as the alternating plant.*

The old type of Zipernowsky transformer, with iron wire wound round the copper coils, has been abolished. The iron part is built up of circular, flat, ring-shaped discs of iron, which are firmly clamped together by iron clamps, which form the support of the instrument. The copper coils are wound upon the segments of the rings between the clamps, the primary coil being underneath the secondary. The transformer has an iron circular disc at top and bottom, fixed to the clamps, and this enables the



FIGS. 7 AND 8.—ZIPERNOWSKY 7·5 UNIT TRANSFORMER.
(Scale 1⅛ in. to the foot.)

instrument to be easily rolled about without injury, and facilitates handling. On the top are several porcelain discs, on which are placed the terminals and fusible cut-outs, which are somewhat after the Hedges system, and consist of thin fusible strips of metal held between asbestos millboard, so that they can be slipped in and out with the greatest ease. They are all of ten horse-power, with about four amperes in the primary and seventy-five in the secondary, the working pressure in the secondary circuit is 110 volts, but the secondary coil has three terminals, as shown, one half way along the length of wire to enable a three-wire system to be employed when arc lamps are wanted, which consume with their resistances 55 volts each. Drawings of these transformers are given at Figs. 7 & 8.

The small alternators are intended to work 1000 60-watt lamps; they have each 20 poles, and run at 250 revolutions per minute. The steam pressure is 120 lbs.

* The details of the station are from Professor Forbes' Paper, "Journal Inst. Electrical Engineers," Vol. XVIII.

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The large dynamos have forty poles each on the revolving field magnets; both field magnets are divided into two series in parallel. The efficiency of these machines is said to be 90 per cent., including the exciting current; they are so constructed that the cover which contains the armature coils can be drawn away by means of a handle over the electro-magnet ring without the necessity of using any hoisting tackle. The construction of the armature is such that any single coil can be removed in a few minutes or exchanged. The iron plates of which these armature sections are made are T-shaped, so that the centre of the coil is filled with iron; in the smaller machines there is not nearly so much iron in the coils. The energy used in exciting the 600 horse-power machine at full load is said to be $3\frac{1}{3}$ per cent. of the load. Fig. 9 shows the construction. The T-shaped iron plates of the armature (c^1) are pressed together by bronze press plates (S) and a screw (c''); the wire bobbin is then slid on, and held by screws; these segments are fastened to

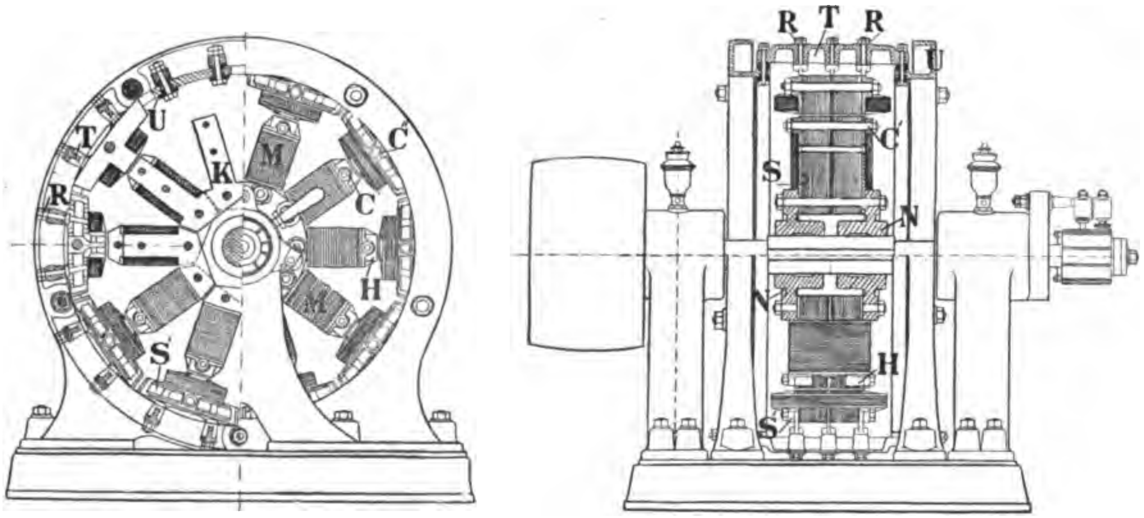


FIG. 9.—ZIPERNOWSKY ALTERNATOR.

two traverses (T) by the screws (R), which are in turn screwed with an insulating layer (U) to the side-plates of the framework of the machine. The field magnet wheel consists of U-shaped soft iron sheets (K), so arranged as to form a star, to which is added a similar star, with an insulating layer between, placed in such a way that the interstices between the sheets composing the lower star are covered by the sheets on the upper star; in this way many laminæ are put one upon the other, until there are sufficient to form the whole electro-magnet wheel. The pile so formed is then pressed together to form a compact whole by means of two stiff discs, two bosses (N), and the screws (C). The bobbins (M) are slipped on to the core (K), and held down by means of the bobbin-holder (H) and screws (C^1). The subdivision of the iron in the field magnets is necessitated by the teeth of iron in the armature projecting inwards through the coils.

Fig. 10 shows the mercury switch-board; it is about 8 feet high and 17 feet long. It is divided into four sections, one for each dynamo, and each section connected with the

two poles of the dynamo. Two vertical bars descend from these at each of the six parts allotted to the six circuits; six pairs of horizontal bars are connected to the six pairs of feeders, these pairs being one over the other. At each feeder-section a pair of vertical copper bars descend from the horizontal feeder bars corresponding to that section. Thus we have at each feeder-section two vertical dynamo bars and two vertical feeder bars, the lower ends all being at the same level. Mercury cups can be raised to connect each dynamo bar with a feeder bar, or lowered to disconnect them. The chief object of the switch-board is to switch any number of dynamos in or out of connection with any feeders simultaneously and instantaneously.

Referring to the diagram, in the normal condition the crank (A) and handle (B) would be as shown in the side elevation, one crank to each mercury cup (C). If it be required to put on to the dynamo the feeder No. 6, and take off No. 1 from the dynamo

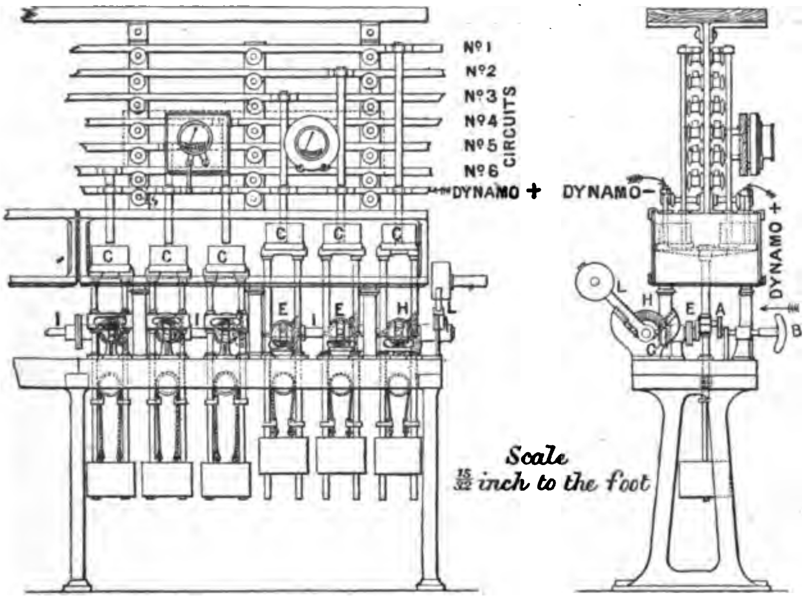


FIG. 10.—MERCURY SWITCH-BOARD, ROME.

represented by this part of the switch-board, the handles (B) with cranks (A), corresponding to these feeders, are pushed bodily to the left; the web of each crank is thus made to fit in a vertical slot in the disc (E), which disc is connected to the level wheel (G) by a hollow spindle, to which (G) is keyed, this level wheel gearing with the level wheel (H) keyed on to the shaft (I), running the whole length of the switch-board. The crank of No. 6 would be diametrically opposite that at No. 1, since one was disconnected and the other connected to a circuit. The lever (L) is then thrown over against the other stop, causing the crank No. 6 to be raised from its lowest to its highest position and that of No. 1 to be correspondingly lowered.

Steam is supplied by fourteen boilers of the water tube type, the steam pipes being so arranged that any portion can be stopped off in case of accident or repairs.

An interesting feature of this central station is the fact that it is the property of the Roman Gas Company, who had the foresight to alter, or rather add to, their original title, "The Company for the Illumination of Rome with Gas," the words "and other systems"; thus following the example of the many American gas companies, who speedily recognized that the electric light would not only be an important addition to their business, but that, by taking it up themselves, rival companies were practically kept out of the field.

Siemens' concentric conductors are used throughout the city. The feeders, which are each 220 square millimetres in section (0·35 square inch), all go to the Piazza Venezia, and then branch off into three mains in different directions. The loss in the secondary circuits due to loss in the feeders at present is only 0·6 volt at the maximum, and that due to the mains is the same, the length of the feeders being 1600 metres.

Fig. 11 shows the drawing of the Siemens and Halske junction boxes, and also

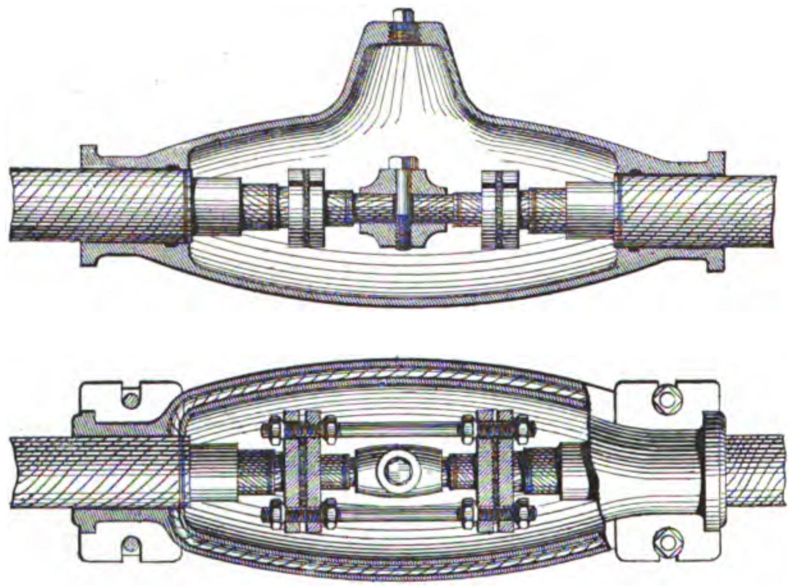


FIG. 11.—JUNCTION BOX BY SIEMENS AND HALSKE.

the attachment by clamps of the two ends of the inner and outer concentric cores. The cables are laid in a wooden box, and this is filled with cement.

Siemens and Halske's system of concentric mains is fully described later at page 136.

The sub-station high-pressure system has been thoroughly worked out in Rome. Every nest of about 2000 lamps is served by a sub-station containing a bank of twelve transformers, each of seven-and-a-half kilowatt capacity. Means are provided to cut transformers in and out as the load comes on and off. The great waste of the idle transformer is thus prevented; and by banking them in this way only half the total number of transformers is required, and it enables these appliances to be used in the most efficient maner—*i.e.*, at full load.

THE VENICE CENTRAL STATION.

This installation has been selected as an example of the Zipernowsky-Déri-Bláthy alternating system, not on account of its size, as it is in that respect inferior to those at Rome and Leghorn, but its construction was undertaken in the face of many difficulties, which have been overcome, and its operation has been attended with great success.

Venice, as everyone knows, is a city peculiar to itself. Every yard of ground on the group of islands, which can hardly be called *terra firma,* is built over, and it was only by pulling down a palace, dating from the sixteenth century, that a site for the central station was obtained. The foundations of the buildings are on piles; in fact, the greater part of the wedge-shaped piece of ground on which they stand is filched from the adjoining canal, which at one time was not confined to the regular channel it is now. Great care was bestowed on the foundations of the engines and dynamos; a strong wooden framework is first securely attached to the piles, and about three feet of concrete is run over the whole, a rubble foundation securing an even bearing on the earth beneath. The machinery rests on a mass of brickwork, which is altogether isolated from the outside walls.

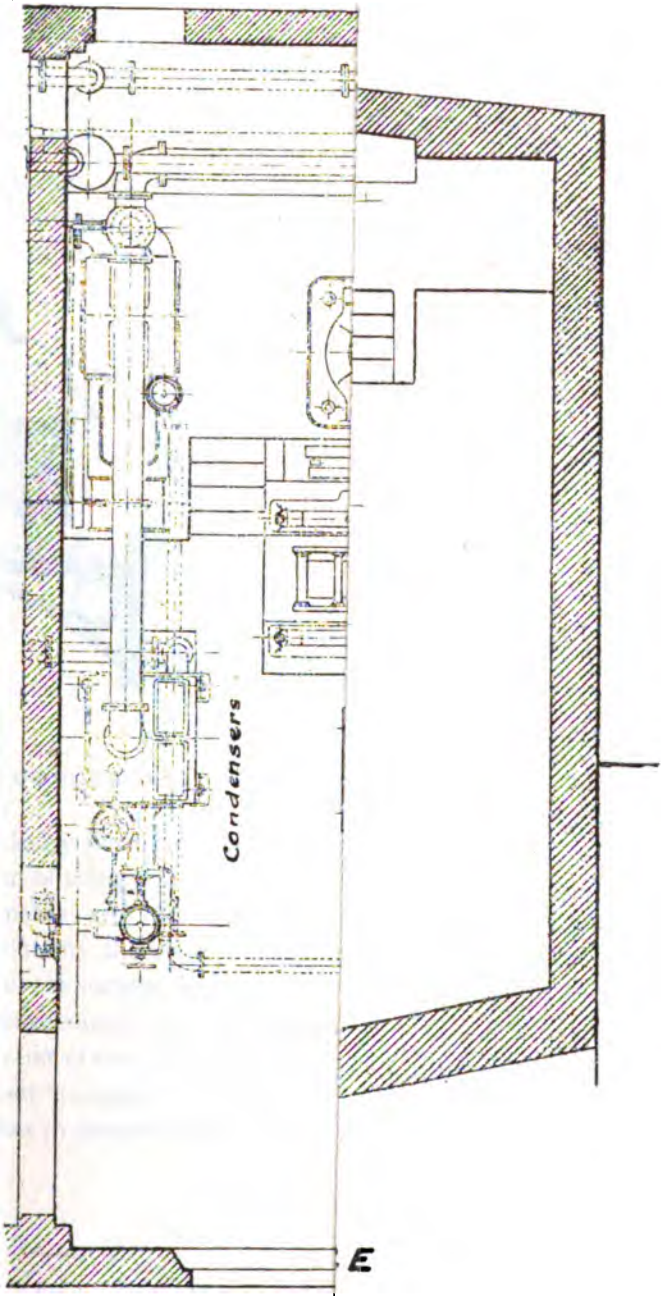
The electrical equipment at present is as follows (*see* Plate II): Four complete sets of direct-coupled engines, alternating-current dynamos and exciter, each group capable of a maximum output of 80,000 watts—40 amperes at 2000 volts; the speed of the combined plant is fixed at 250 revolutions per minute, and at full work each group is said to maintain 1500 lamps of sixteen candles. The dynamo is of the well-known Ganz type, in which the external armature is fixed, and is composed of twenty bobbins having cores of laminated wrought-iron connected in series. The revolving armature has twenty bobbins, also divided into two circuits of ten each; the number of alternations is 5000 per minute. This low number of changes of polarity is always adopted by Messrs. Ganz for every type of alternating machine, and is said to be advantageous, in spite of the increasing weight and size of converters which it necessitates. The exciter is of the Gramme type, and furnishes 4000 watts at the same low speed of 250 revolutions per minute. Messrs. Ganz do not make arrangements with this type of plant for withdrawal of the armature of the alternating machine, which was noticeable in those at the older Rome installation; they also find the heating of the coils to be much reduced by increasing the air space between the magnets and bobbins, which is at Venice about 20 millimetres. The steady working of the plant is mainly due to the low speed and to the method adopted for coupling to the engine shaft, which obviates any strain due to bad alignment of the two shafts. The number of sets of plant will be increased to seven, which with one spare set will enable 9300 lamps to be run at once; at present, about 5600 are worked, which is not a bad result, as the erection of the station was only commenced in 1890.

The steam engines are vertical compound tandem, condensing, by Tosi, Legnano; the high-pressure cylinder is 325 millimetres diameter, and the low-pressure 475. The valves are of the piston type, and are arranged so that the expansion can be varied. In outward appearance the engine resembles the ordinary kind, the lagging being carried upwards from the low-pressure cylinder. The compounding in this way, although common enough on board ship, has not been extensively adopted for electric light installations. The manifest advantages a vertical has over a horizontal engine, besides its regularity of piston speed, are that less floor space is required, and compactness is secured without sacrifice of economy; these engines have been guaranteed to give a horse-power hour with 19 lbs. of steam, the working pressure being 120 lbs. on the square inch. Although, on account of the abundance of water, the exhaust steam is condensed, separate pipes are fitted for free exhaust, in the event of a breakdown of the separate engine which works the air pumps.

The boilers are an Italian adaptation of the well-known Babcock-Wilcox type. The difference is chiefly in the way in which the ends of the water tubes are connected, in order to allow good circulation and stop the priming which the American boiler is not always free from, especially if the feed water is not good; and it certainly is not at Venice, as, in spite of all regulations to the contrary, the canals are the receptacle for the house drainage, which the small amount of tide is powerless to remove.

The system of working is very simple. Groups or units of plant are added as the demand increases. All the machines are coupled in parallel, both the alternators and their exciters; it would not be safe, however, to switch a spare machine on to the circuit of one heavily loaded. Recourse is had to an artificial resistance, which is usually a bank of lamps; these can be added until the load of the two machines is equal, and their running together assured. The E.M.F. of the primary circuit is kept constant by the method of adding or diminishing resistances in the field magnet circuit of the exciting dynamos, which are of the shunt type. For large variations the regulation is effected by hand, but for small variations by means of the Bláthy rheostat—an apparatus which, by means of a solenoid, causes a number of wires to gradually enter a cup filled with mercury. The object in view is not to maintain the E.M.F. constant at the terminals of the primary current in the station, but at the tranformers. To bring a separate wire back from each transformer in order to measure the fall in E.M.F. would be impracticable, apart from the cost of the wire, so that a special arrangement had to be designed, which controls the pressure at the transformers and keeps it constant. The primary circuit passes through two special converters; one of which is the equalizer, and the other the reducer, which serves to work the automatic rheostat, and also permits an ordinary voltmeter to be employed.

The method of distribution is, as a rule in Italy, by aërial cables, which are run along the fronts of the houses; but underground cables have also been employed for some time, and have carried the full pressure of 2000 volts without any breakdown. The concentric cable usually employed is similar to that which has been recently laid down for the London Electric Company by Messrs. Siemens.



STATION

The output, weight, and duty of the standard sizes of converters is given by Messrs. Ganz in the following table :—

Output in Watts.	Weight in lbs.	Loss at Full Work.	Work of Magnetisation.	Commercial Output at Full Work.
1875	154	2 per cent.	5·5 per cent.	92·5 per cent.
3750	242		3·5 " "	94·5 " "
7500	396		2·5 " "	95·5 " "
15000	638		1·5 " "	96·8 " "

The converters are installed either in the cellars, or—as in Venice, where this would be impracticable—they are often carried on brackets fixed to the outside wall of the houses, as shown by Fig. 12.

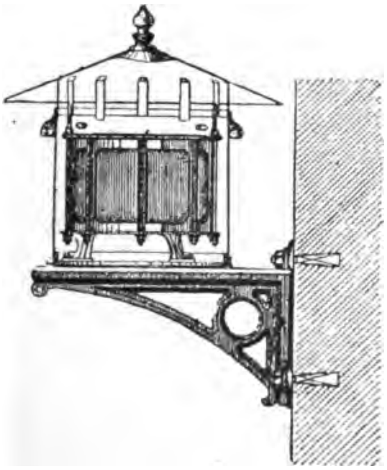


FIG. 12.—TRANSFORMER BRACKET.

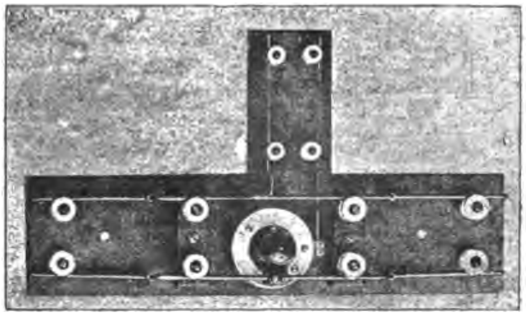


FIG. 13.—SWITCH WITH HOUSE WIRES ON INSULATORS.

Fig. 13 clearly illustrates the method of running the secondary wires into houses, and the system of using insulators instead of casing.

The branches are taken from the mains by means of a porcelain connector, which also contains the switches and cutouts. Insulated cables are always used, except at the connectors, where bare copper facilitates the jointing up. This plan has worked exceedingly well at Venice, and is preferred to casing or lead-encased cables, on account of the dampness of the walls.

The current is supplied by meter, on the Bláthy system,* which gives the amount consumed either in ampere hours or watt hours. It is said to work with one-tenth of an ampere.

* *See* Fig. 49, page 82.

LEGHORN.

The central station has been established since the 29th of September, 1888. It is fitted on the same system, and differs very little from those previously described. There are three alternating-current machines, separately excited, of 80,000 watts (40 amperes × 2,000 volts) each, which are directly coupled to horizontal engines running at a speed of 250 revolutions per minute. The exciting dynamos are driven by belting from the main engines; two of these dynamos are sufficient to excite the three alternators, which are coupled in parallel. The boilers are of the Babcock-Wilcox type.

The number of Edison lamps, sixteen candle-power, fixed this year was about 2000, of which 1900 are often all lighted at the same time. The service commences each day one hour before sunset, and ceases one hour before sunrise.

The accompanying illustrations (Figs. 14, 15, 16 and 17) show the interior of the station, and are taken from photographs.

INNSBRUCK.

This installation was started in August, 1889, and is the property of the Augsburg Company, who also supply the gas to the town. The motive power is taken from the Mülhauerklamms (Fig. 18), a stream which is nearly two miles (3 kilometres) from the town. Of this torrent 390 feet are sufficient to give the necessary fall, the water being led by iron pipes to the turbine-house (Fig. 19), where two turbines (Fig. 20), each of 125 H.P., drive two alternate-current dynamos of the ordinary Ganz pattern (Fig. 21), each giving an output of 80,000 watts. Each dynamo is excited by a separate continuous-current machine, the current (40 amperes × 2000 volts) being led to the town of Innsbruck by overhead wires of naked copper, but in the town itself underground concentric cables are employed.

This was one of the first stations which furnished motive power by means of alternating currents. The number of motors installed is increasing rapidly.

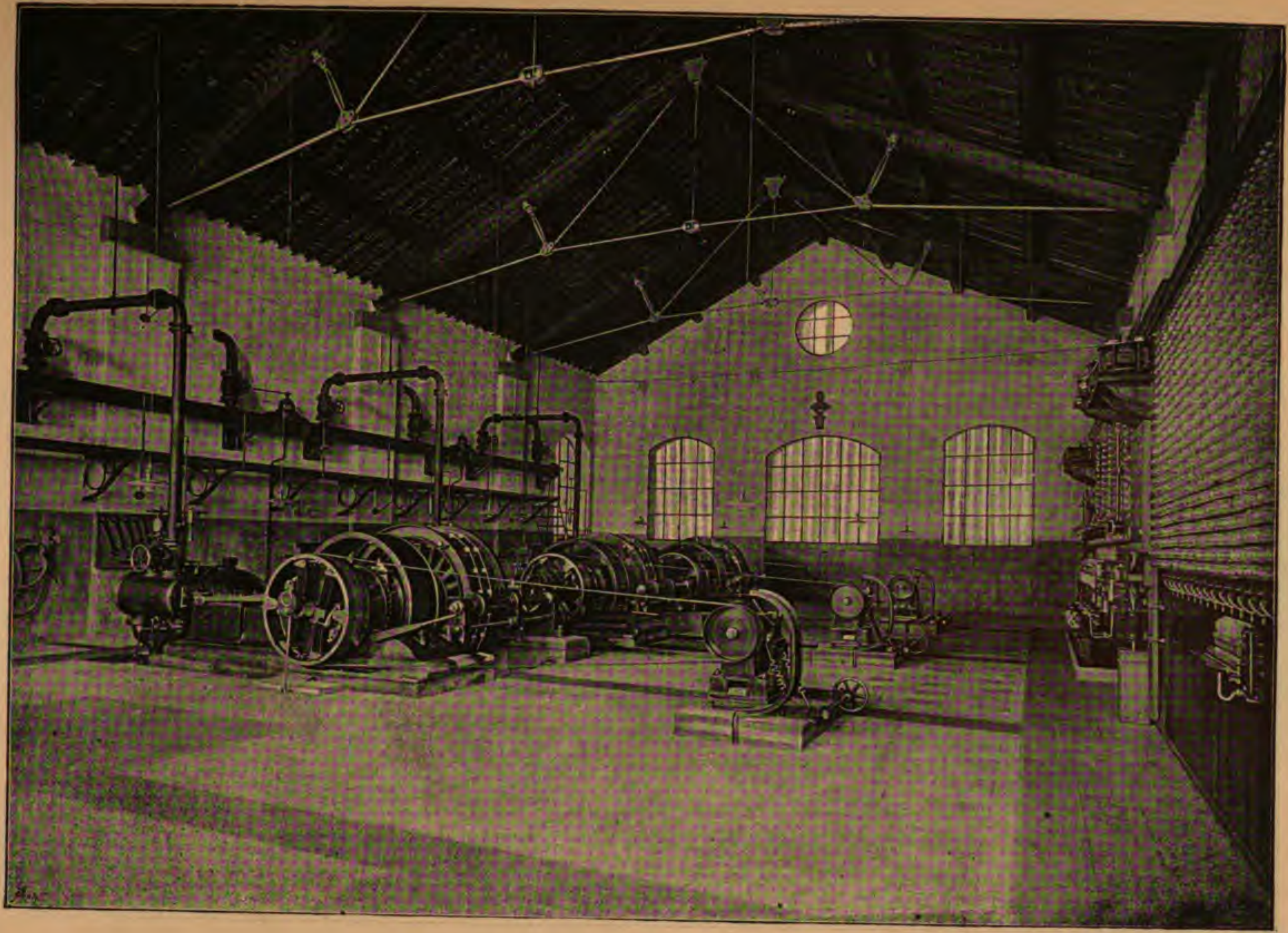


FIG. 14.—ENGINE ROOM, LEGHORN CENTRAL STATION.

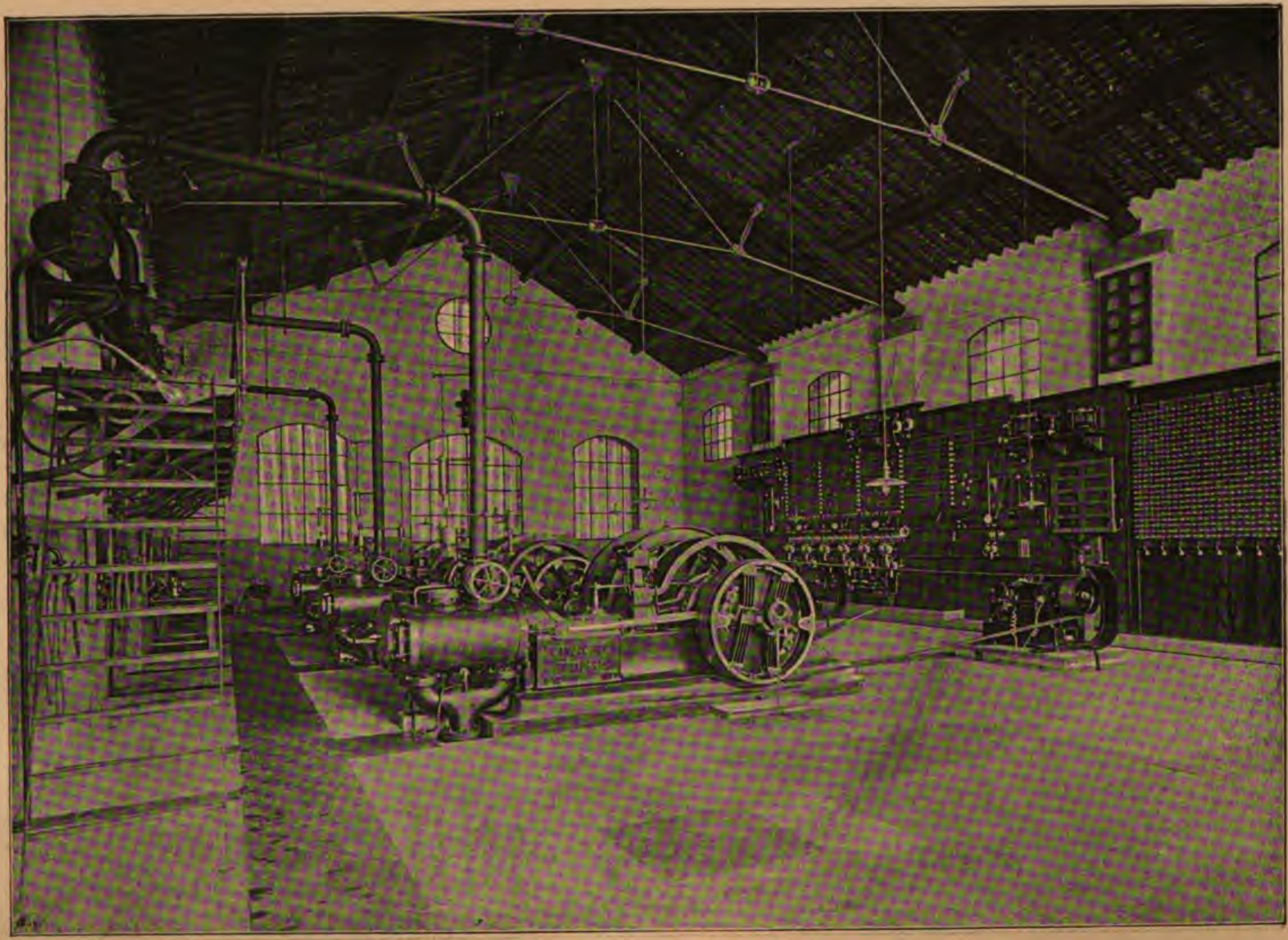


FIG. 15.—ENGINE ROOM, LEGHORN CENTRAL STATION.

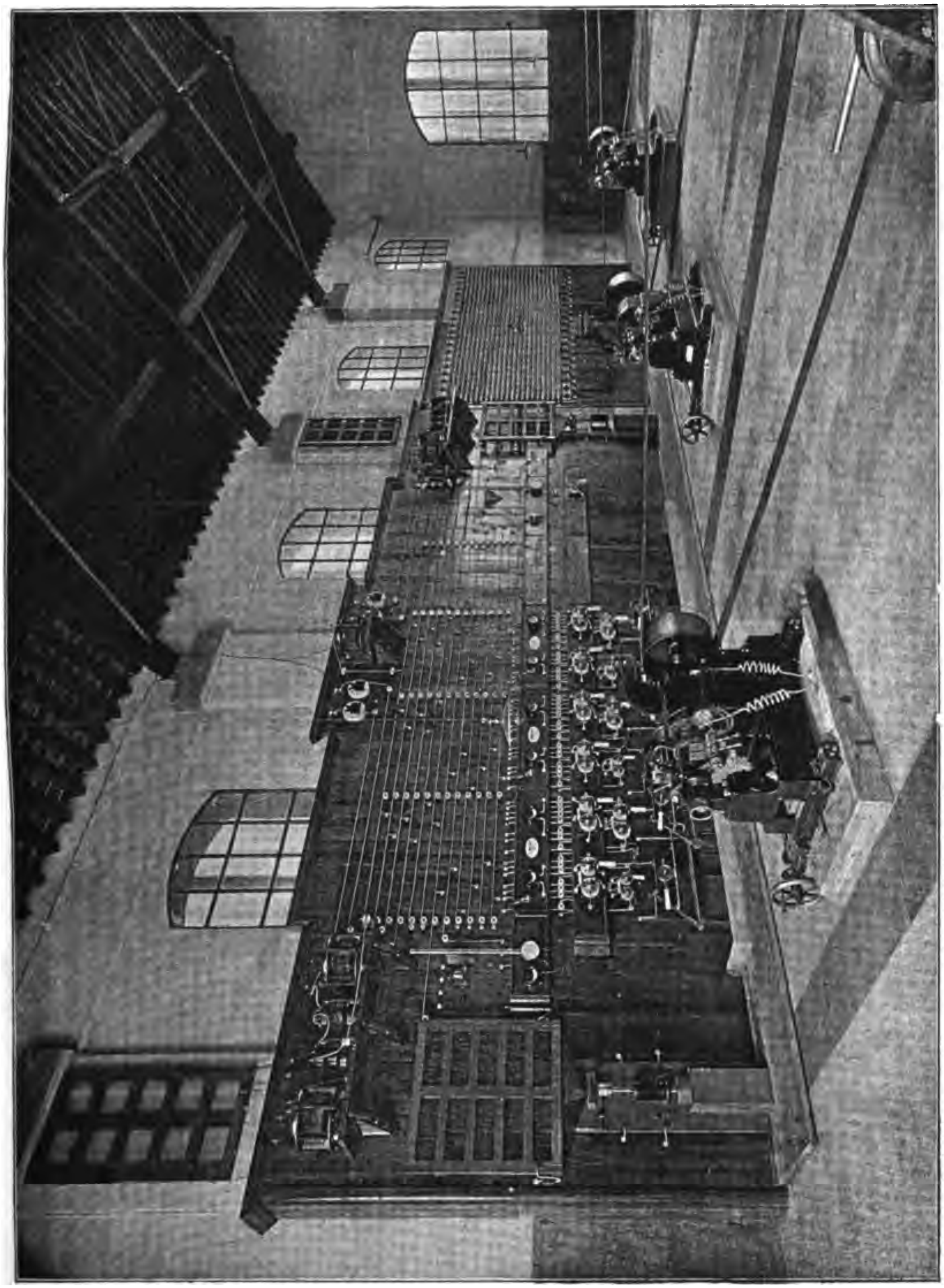


FIG. 16.—SWITCH-BOARD, LEGHORN CENTRAL STATION.

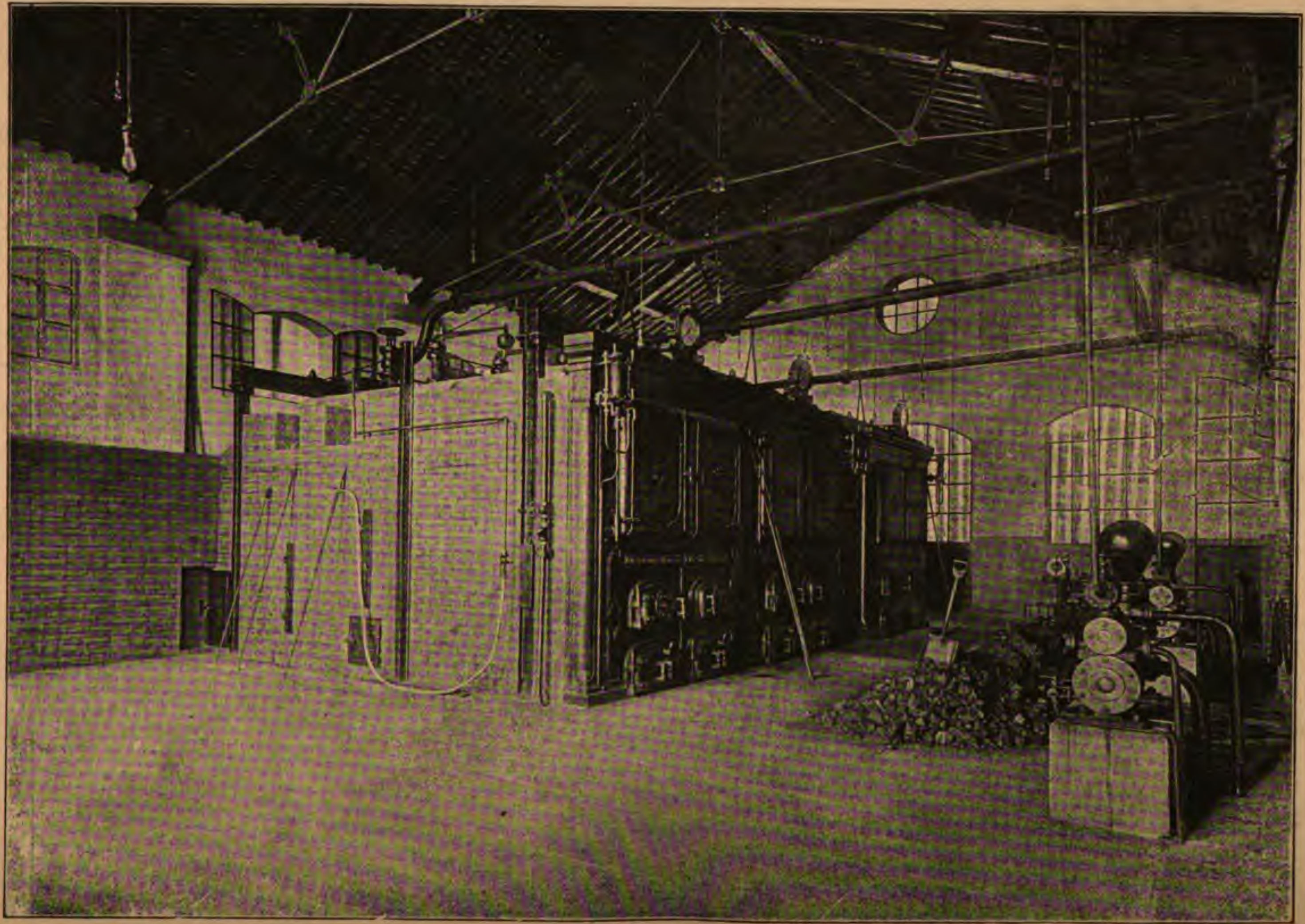


FIG. 17.—BOILER HOUSE, LEGHORN CENTRAL STATION.

FIG. 18.—THE MÜLHAUERKLAMMS, INNSBRUCK.

FIG. 19.—TURBINE HOUSE, INNSBRUCK.

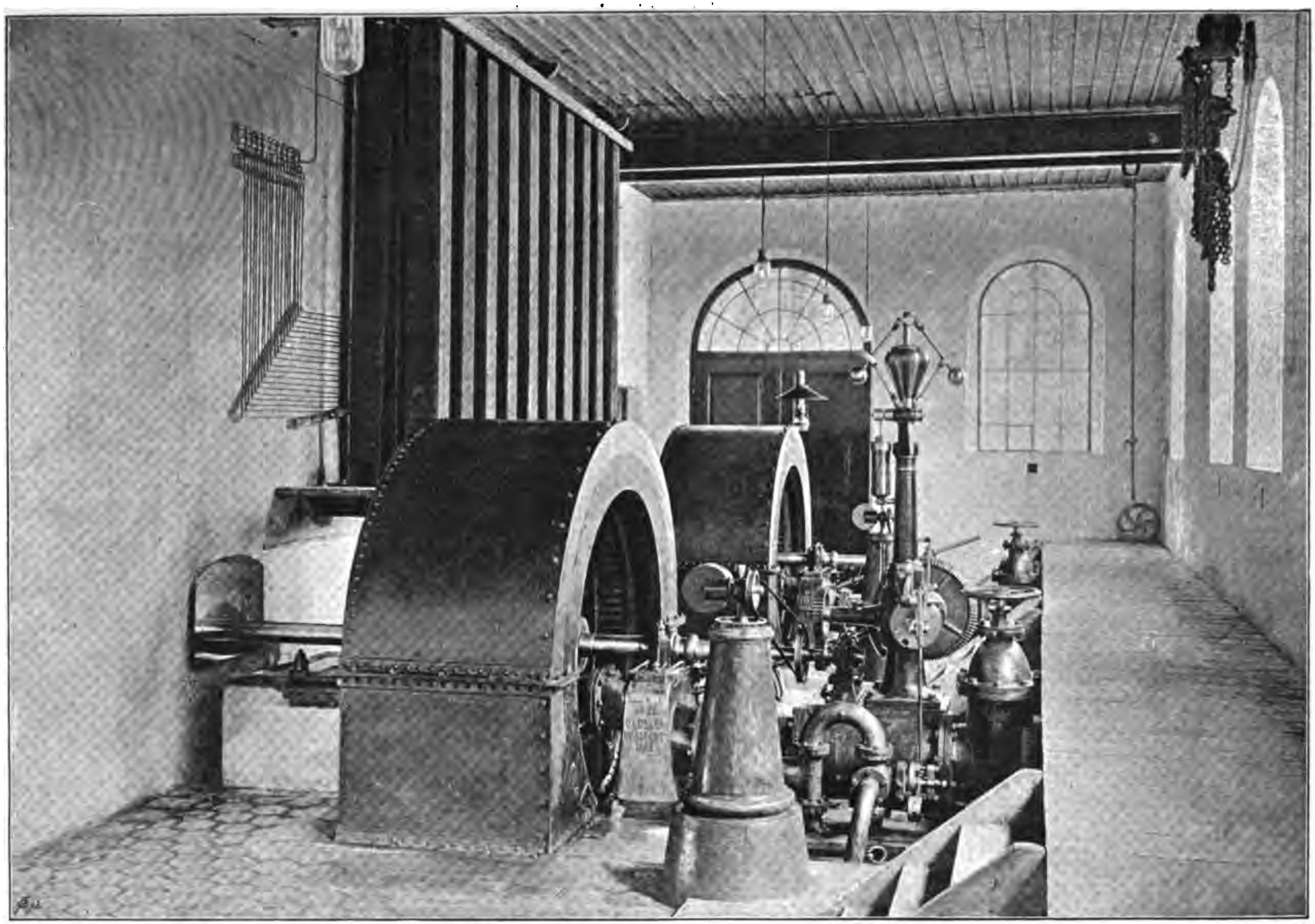


FIG. 20.—INTERIOR OF TURBINE HOUSE, INNSBRUCK.

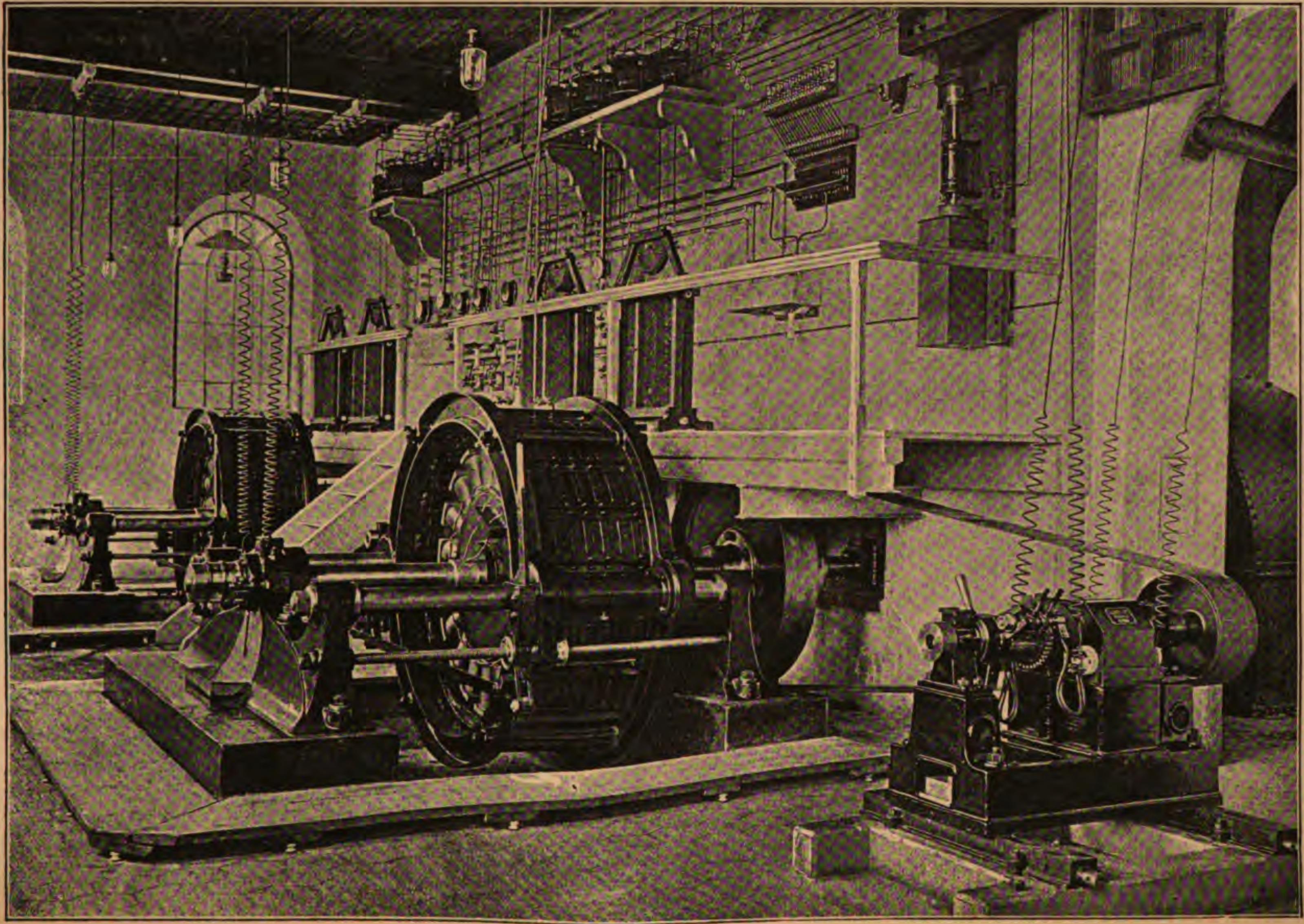


FIG. 21.—DYNAMO ROOM, INNSBRUCK.

MARIENBAD.

The central station at this town was the result of the private enterprise of the proprietor of the baths, who, having lighted his establishment in May, 1889, was invited by the Municipality to also illuminate the town. The building is of an unpretentious character, and is situated near the railway station, about 2000 yards outside the town of Marienbad, and occupies about 620 square yards. Four

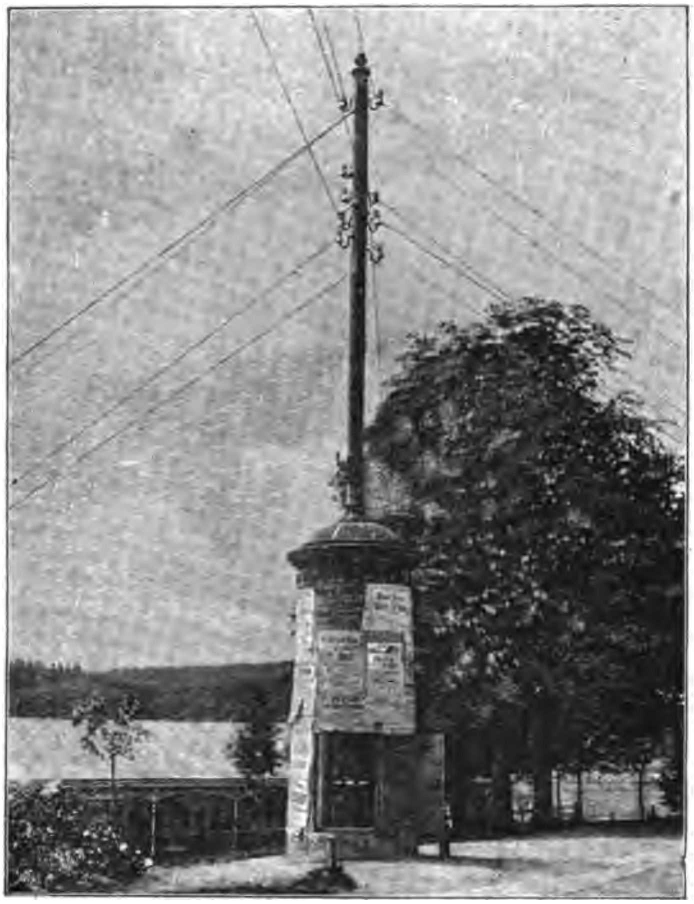


FIG. 22.—STANDARD FOR HIGH AND LOW TENSION MAINS, WITH TRANSFORMER HOUSE, MARIENBAD.

Zipernowsky alternators, each giving 50,000 watts at 500 revolutions per minute, furnish the current, about 80 H.P. being required for each machine. They are driven by Westinghouse engines of Alley and Maclellan, Glasgow; the boilers, which have been supplied by Ringhoffer of Smichov, Prague, work at 105 lbs. pressure; the feed water is pumped from a well on the premises, and is heated to 70° Centigrade. The primary and secondary circuits are run on insulators fixed on poles, as shown

by Fig. 22, leaving a space of 30 metres between each support. Outside the town ordinary telegraph posts are used, but inside they are ornamental, and also serve to support both the arc and incandescent lamps. The transformers are either placed in kiosks, which are so commonly used abroad for advertizing purposes, or at the base of iron columns, which also serve for supporting the posts. Both the arc and

FIG. 23.—ELECTRIC LIGHT STANDARD.

incandescent lamps are in parallel. After midnight the arc lights in the streets are extinguished and replaced by incandescent lamps, which are carried on light brackets off the poles, as shown on Fig. 23. All the circuits are protected by lightning protectors, as thunderstorms are very frequent. The interior arrangement of the station is shown by Figs. 24 and 25.

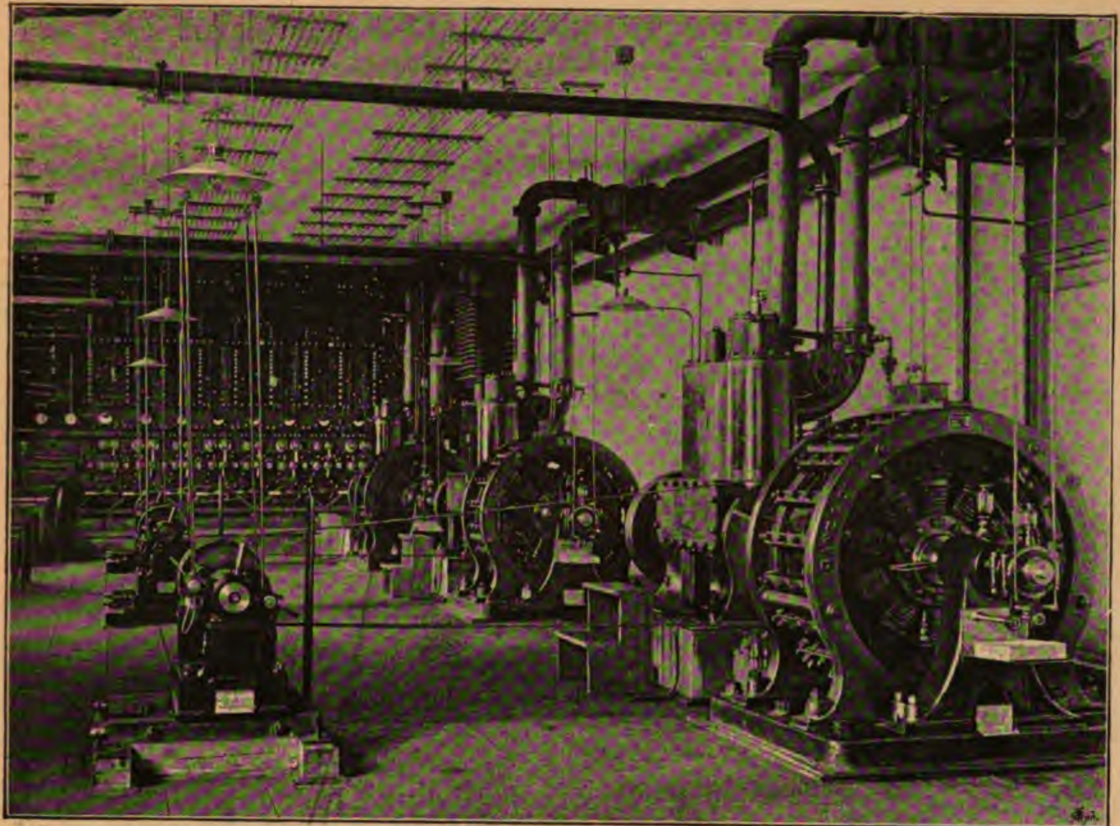


FIG. 24.—CENTRAL STATION, MARIENBAD.

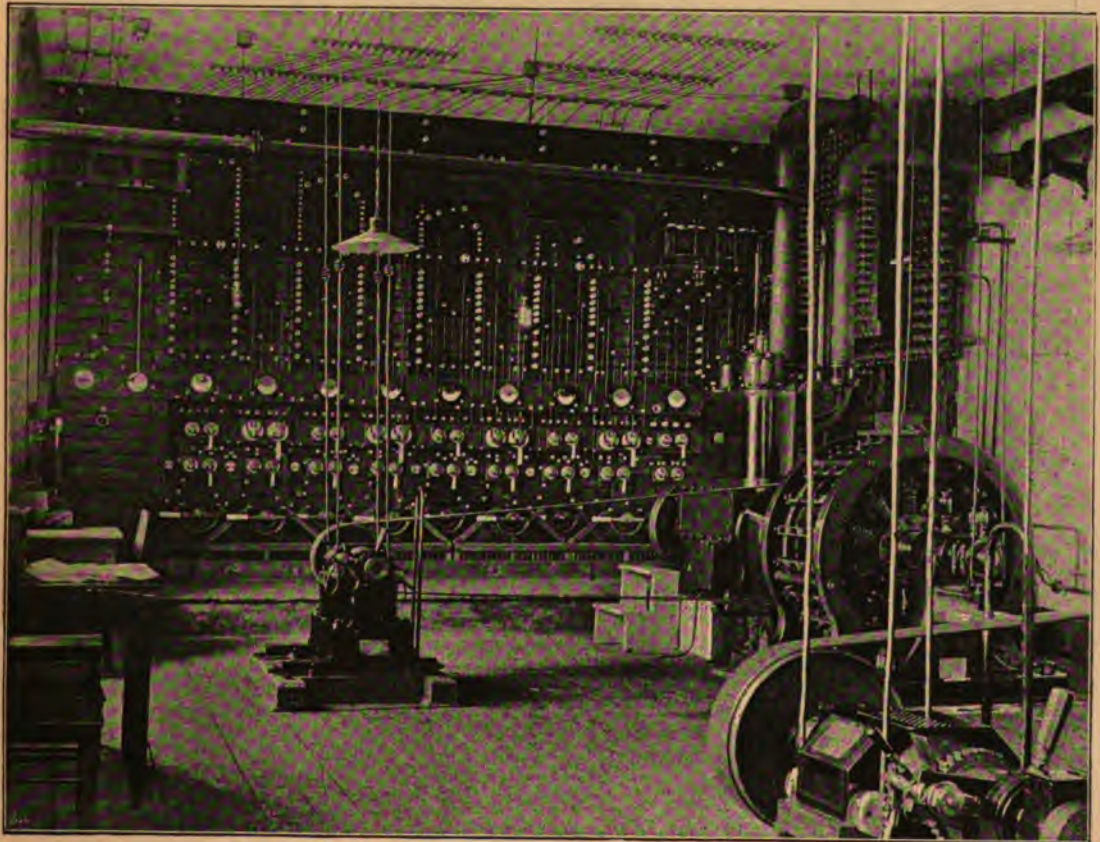


FIG. 25.—CENTRAL STATION, MARIENBAD.

THE KARLSBAD CENTRAL STATION.

This station provides for 76 arc lamps for street lighting, 40 for private use, and about 3000 glow lamps, divided between 76 private installations.

As Karlsbad is a well-known health resort, it was not desirable to have electrical works within the town. For this reason it was decided to unite the electric-light station with the town water-works, which are situated at Donitz, about two miles from Karlsbad. The station is provided with five Babcock and Wilcox boilers, having 1300 square feet heating surface (Fig. 26); four steam engines of 125 H.P., each

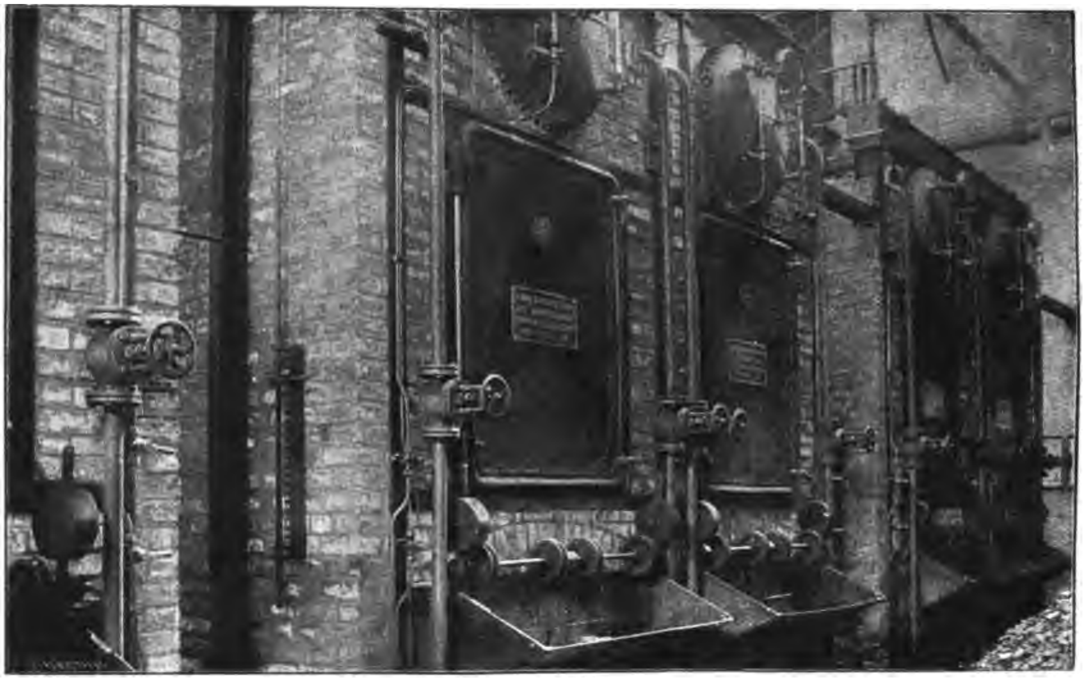
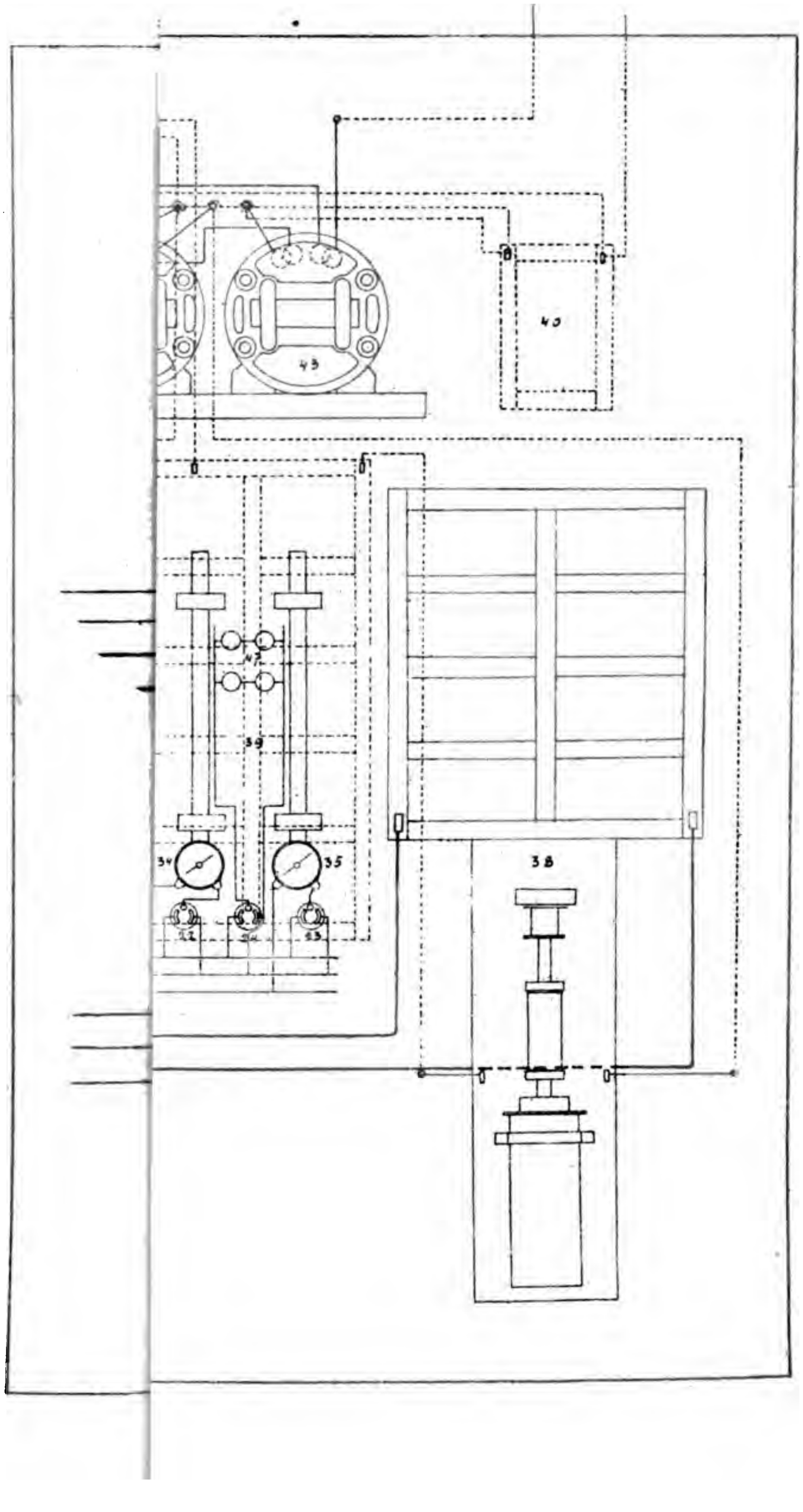


FIG. 26.—BOILER HOUSE, KARLSBAD.

driving directly, at 360 revolutions a minute, an alternator of 80,000 watts (2000 volts × 40 amperes), Fig. 27; these machines work in parallel, and are each provided with an exciter also directly coupled, so that the engine, alternator and exciter run together.

The switch-board of the Karlsbad station is shown in outline by Plate III. and is very much the same as the one generally used by Messrs. Ganz for all their installations. For description of the Plate see the explanatory table.

From the engine-house to the boundary of the town, two mains of ·32 inch diameter copper wire are erected on telegraph poles along the edge of a wood; the


43
40
47
39
34
35
38

lines are continued within the town by underground lead-covered cables protected with iron sheathings.

Figs. 28 and 29 illustrate the way the arc lamps are suspended.

The transformers are put up in various parts of the town, some in the houses, the rest in specially prepared sites (see Fig. 22). The arc and the incandescent lamps are both run in parallel, an intermediate terminal being provided on the transformers, so that the arcs can be so connected as to receive only 50 volts.

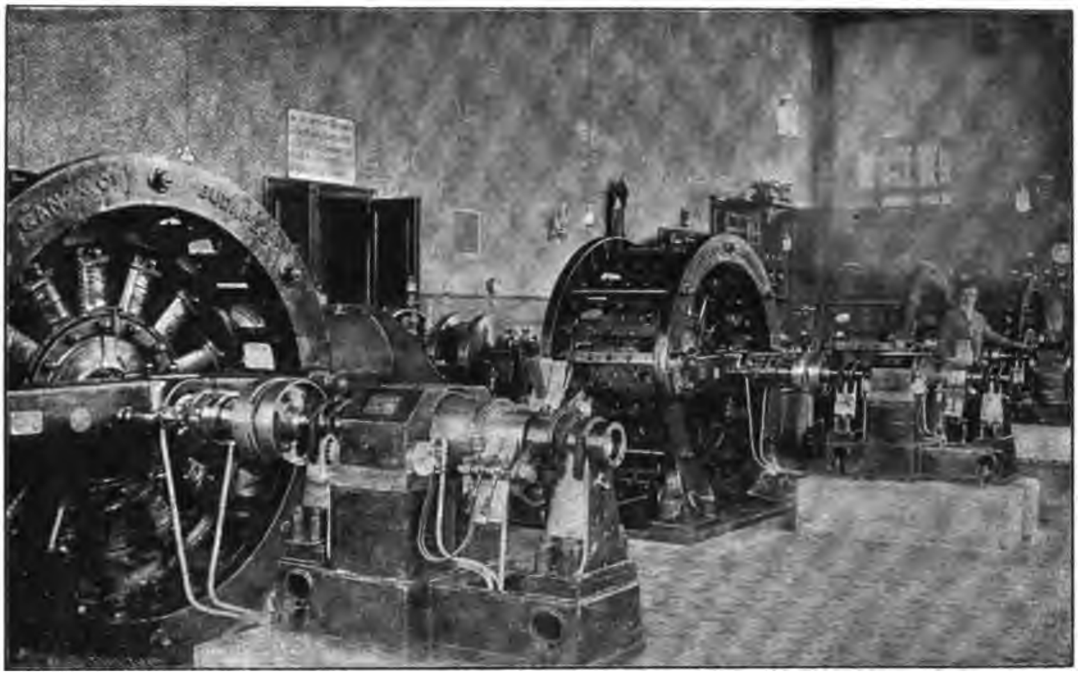


FIG. 27.—DYNAMO ROOM, KARLSBAD.

EXPLANATION OF PLATE III.

1–3 Alternate-current machines.
4–6 Exciters.
7–9 Rheostats for field magnets of alternators.
10–12 Rheostats for shunt coils of exciters.
13–18 Mercury cut-outs.
19–21 Exciter switches.
22–23 Voltmeter switches.
24 Switch for phase-indicator.
25 Voltmeter switch.
26 Ammeter for main current.
27 „ „ rheostat.
28–30 Ammeters for alternators.
31–33 „ „ exciters.
34–35 Cardew voltmeters.
36 Continuous-current voltmeters.
37 Rheostat.
38 Automatic ditto.
39 Resistance for automatic coils.
40 Equalizing resistance.
41–42 Reducers for 34, 35 and 47.
43 Transformer for lighting the central station.
44–45 Reducer and equalizer for automatic apparatus.
46 Equalizer to 43.
47 Phase-indicator.
48 Lead fuses.

FIG. 28.—ARC LAMP STANDARD.

FIG. 29.—ARCH FOR ARC LAMP.

VALRÉAS AND DIEU-LE-FIT, FRANCE.

This installation offers a good example how two country towns, situated about 12 miles (20 kilometres) apart, in different provinces, are lighted from the force produced by a fall of water which is hidden away in the mountains. A reservoir, having a capacity 800 electrical horse-power, was first made, so as to dam up a fluctuating mountain stream, and enable a constant head of 82 feet of water to be obtained. The water, under pressure, is brought by two wrought-iron pipes, each of 32 in. diameter, to two turbines, each of which is constructed to give 50 horse-power at a speed

FIG. 30.—CENTRAL STATION FOR VALRÉAS AND DIEU-LE-FIT.

of 180 revolutions per minute. Each turbine drives an alternating-current dynamo of old type (2,000 volts × 12 amperes = 24,000 watts) and the exciting dynamos which can produce 3000 watts. Each of the two towns is supplied from one group of machines, the current being taken to Valréas (Vaucluse) in one direction, five kilometres (three miles), and Dieu-le-Fit (Drôme), fourteen kilometres (nine miles), in the other. Fig. 30 shows the central station, which is of most unpretentious character. The whole of the circuits, both in and outside the two towns, are of naked copper wire, carried on bell insulators fixed on telegraph posts. The shortest line, that from the turbine house to Dieu-le-Fit, is of siliceous bronze wire, 3·2 millimetres (·13 in.) dia-

meter, and of a resistance of 11·8 ohms. The line to Valréas is of the same material, but consists of a cable of thirty-three strands, each one square millimetre sectional area, and 16·1 ohms total resistance. Two telephone wires are carried on the same poles, connecting the towns with the central station. In the towns the wires are often run on supports fixed to the walls of the houses, the transformers being also carried on brackets and covered by bell-shaped weather guards. Fig. 31 is taken from a photograph of one of the streets in Dieu-le-Fit. This plan appears to be far less objectionable than that we are accustomed to in England; and, curious to relate, there is no law which authorizes either the Government to run their telegraph and telephone lines or the electric light companies their leads along the houses, but no one seems to object; and, in fact, of the two evils it is much better to allow a light bracket to be fixed to

FIG. 31.—A STREET IN DIEU-LE-FIT.

the front, than a pole with its numerous guys on the roof of a house—the state of the former can always be ascertained, while a pole may, unnoticed, be breaking away or seriously damaging a roof.

No accidents have occurred, although both primary and secondary circuits are of naked wire. The length of conductors is very different in each town. Dieu-le-Fit is long and straggling, giving a distance of three kilometres (about two miles) between the extreme lamps; whilst Valréas embraces almost a perfect circle.

In the former, there were sixty public lamps in the streets; sixty in private houses.

In Valréas, seventy public lamps; 180 private.

The installation has been at work since 1888, and has given great satisfaction.

THE VIENNA CENTRAL STATION.

BY THE INTERNATIONAL ELECTRICAL COMPANY, VIENNA.

Up to the present, the most important installation in Austrian-Hungary for the distribution of electricity by alternating currents has been that erected at Vienna by the International Electrical Company, which embodies the principles of the most modern scientific progress; but the short time the installation has been working prevents statistical data being given of the financial results. The works, designed for an output of 5,000,000 watts, or 100,000 glow lamps of sixteen candle-power, are situated outside the town in the vicinity of the Danube (Fig. 32). These consist of two buildings, in one are the dynamos, engines and boilers; in the other the steam pumps and filters, also the mechanics' and smiths' shops. The water for the condensing engines is obtained from a spring in the court; after use, as much as required, having a temperature of 35°–38° C., is pumped through the filters, and used as feed-water for the boilers. In the boiler-house there are at present six tubular boilers by Steinmüller, with 2,620 square feet heating surface each, tested for a pressure of 150 lbs. on the square inch; foundations are also ready for two more. More than a quarter of the proposed machinery is put up, one side of the building having a temporary wall to allow facilities at any time for extensions. In the boiler-house there are three Worthington pumps, with foundations for two additional; one pump serves for the condensation water supply, a second for feeding the boilers, the third remaining in reserve. The coal for the boilers is brought by means of trucks on rails. For the waste from the furnaces there is a passage below the boilers, from which it is taken to the yard by a lift. In the machine-room there are four Zipernowsky alternators of Ganz & Co., each coupled directly to a compound condensing engine of the "Ersten Brünner Maschinenfabrik-Gesellschaft." The dynamo, driven by one engine (300 H.P.) at 175 revolutions, gives 100 amperes at 2000 volts; the other three machines (600 H.P.) run at a speed of 125, and have an output of 200 amperes at 2000 volts, the total output of the machines now at work is about 1,500,000 watts. The foundations are prepared for an additional 600 H.P. machine. In the alternators, the field magnets (with radial poles) rotate, serving at the same time as a fly-wheel, and induce alternating currents of a frequency of 5000 per minute in the surrounding fixed armature, the machine being regulated by the continuous current used to excite the field magnets. The advantages of such a machine as this are—its high efficiency, simple and solid construction; also, the connections are made in accessible, stationary parts of the machine. Only a low-tension continuous current passes through the coils of the rotating magnets. There is no appreciable rise of temperature when the machine has been running for a

FIG. 32.—VIENNA CENTRAL STATION.

long time, and the armature can be withdrawn on rails clear of the field magnet for cleaning and repairs. The three exciting machines are Ganz & Co.'s four-pole shunt-wound, giving 150 amperes at 180 volts; speed 375. These machines have been put up in anticipation of future extensions.

On the front wall of the machine-room is placed the switch-board, shown diagrammatically in Fig. 33. Each of the exciters, E_1, E_2, E_3 is provided with a rheostat in its shunt circuit (w_1, w_2, w_3), and by means of the switches (a_1, a_2, a_3) and voltmeters, V_1, V_2, the voltage of a machine can be brought to the right amount before switching it in parallel with the machines already working. In the return wire of the shunt circuit are the Bláthy regulators, AR_1 AR_2, for automatically regulating the potential. The wires, *e*, *e*, supply the exciting current to the field-magnets of the alternators, and switches, r_1, r_2, r_3, r_4, are provided for regulating, and also ammeters, A_4, A_5, A_6 A_7. The currents generated by the alternators pass through ammeters, A_8, A_9, A_{10}, A_{11}, and then to mercury switches, Q^1_1, Q^1_2, Q^1_3 Q^1_4, Q_1, Q_2, Q_3, Q_4, which connect the machines to the mains, S. The rheostats, R, R^1, consist of 48 groups of iron wires placed underneath the station; these resistances, the connections of which can be altered by means of a keyboard, are made capable of receiving 600 H.P. of electrical energy. The alternators, which are similar in voltage and frequency, are switched in parallel when they have been made to synchronize by means of rheostats, as shown by the phase-indicator.

From the central station to the town are laid three main concentric cables, on the Berthoud Borel system, from the works of Jacottet & Co., Simmering, sufficient for supplying 30,000 sixteen candle-power lamps. One cable of a cross section of 2 × 0·16

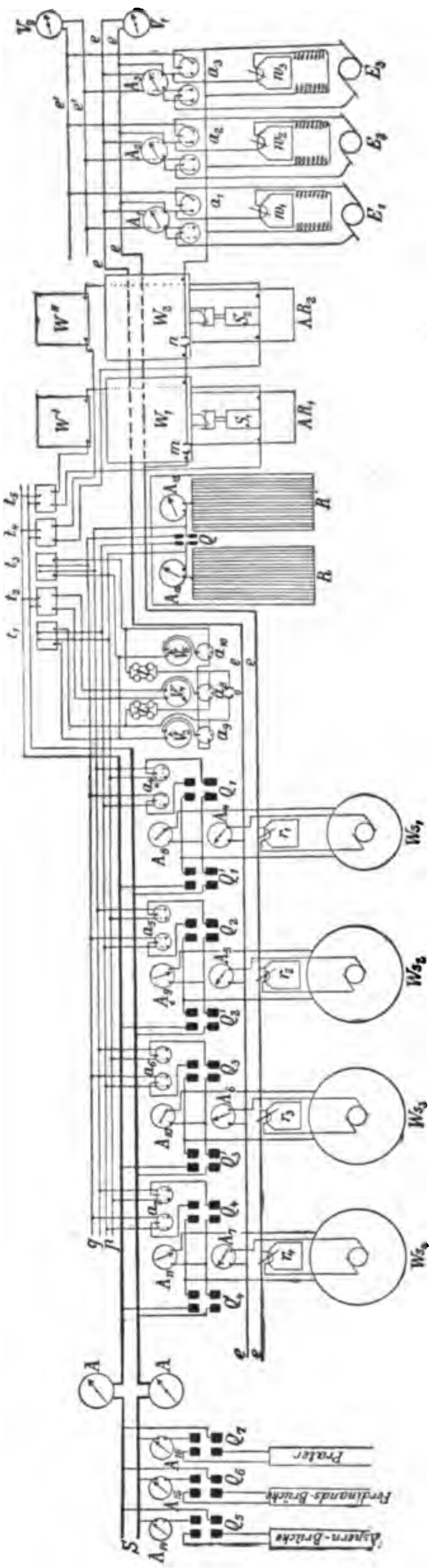


FIG. 33.—DIAGRAM OF SWITCH-BOARD, VIENNA STATION.

square inches, goes direct to the Prater; the other two (of a section of 2 × 0·32 square inches), over the Aspernbrücke, forming two circuits, one for supplying the town itself, the other the outlying districts. The cables, of which 31 miles have been laid—all underground—have excellent insulation, as a rule, over 900 megohms per mile, at 15° C., and before putting down were tested at three times the working voltage (6000). At various points in the network are placed distributing boxes, which serve for connecting branch lines, and for switching off any one main during repairs and extensions. The transformers, which are generally placed in the cellars of the houses, are locked in iron cases. These Zipernowsky-Déri-Bláthy transformers have a working efficiency of 95–97 per cent., the ratio of transformation being 18; they can be considered as part of the distributing network itself, as they are perfectly self-regulating, and require no attention. To provide against overloading, both primary and secondary wires are furnished with lead fuses. The current, which can be obtained from the transformers either on the two-or-three-wire system (50 volts for single arc lamps), is measured by a Bláthy meter. This instrument is extremely accurate and simple; it has no clockwork, being worked by the current itself, and at present is made in two sizes, viz., for 100 and 200 amperes, equal to about 200 and 400 sixteen candle-power lamps respectively. At the central station there is a testing room, provided with all the necessary apparatus, including means for testing the insulation of transformers and wires; for ascertaining the condition of the insulation of the cables; apparatus for calibrating meters, photometers, &c.

This installation has been at work uninterruptedly since November 15, 1890, the total number of sixteen candle-power lamps supplied has been 20,000, substituting glow lamps equivalent to the power consumed by the arcs, which are generally put three in series on to 100 volts.

FIUME ELECTRIC LIGHT STATION.

The International Electrical Company has also erected a central station for Fiume, supplying a number of buildings with electric light, and also working the lifts of the Hungarian Bank. Steam power of 375 H.P. is to be furnished, and there are at present three quick-speed high-pressure engines, each coupled directly to an alternator of 80,000 watts, together with an exciter. The station, harbour, light-house, the whole of the warehouses next to the loading jetties, are lighted, and ships lying in the harbour are also supplied by means of portable lamps. At present, for working the lifts, there are seven 10 H.P. and three 20 H.P. alternate-current motors at work; the former are worked from the secondary circuits, the 20 H.P. motors from the primary mains at 2000 volts. These motors require very little attention, and are perfectly safe. The fact that power is maintained for working machinery naturally

causes a very fluctuating load, but it is so arranged that the changes of load in one machine do not affect the others. This installation has been carried out with a view to extending it at any time for supplying more current for lighting or power.

ELECTRIC LIGHTING OF CASSEL.

CONTINUOUS-CURRENT TO THREE-WIRE SYSTEM, PRODUCED BY MEANS OF AN ALTERNATING-CURRENT MOTOR WORKED BY CURRENT FROM A GENERATOR DRIVEN BY WATER POWER. ALSO DESCRIPTION OF CASSEL AND LAUFFEN-HEILBRONN STATIONS.

BY OSCAR VON MILLER, MUNICH.

At a distance of about four miles from Cassel is a mill, with 100 H.P. available, belonging to the town; situated on the river Fulda; it is used during the hot summer

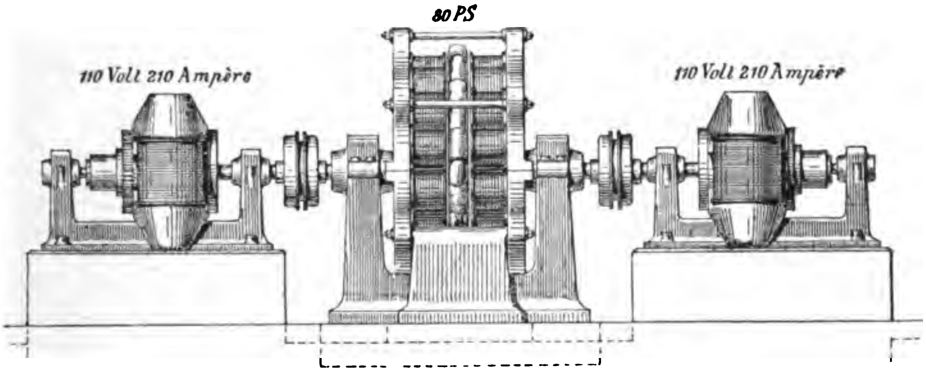


FIG. 34.—ALTERNATE-CURRENT MOTOR, WORKING CONTINUOUS-CURRENT DYNAMOS.

months as a reserve pumping station, to supplement the insufficient water supply As this power is hardly needed during the winter for pumping, whilst on the other hand there is little demand for electric lighting during the summer, such a supply of power can be very well utilized for both purposes.

Plate IV. shows the turbines driving, by means of counter-shafts (to which a reserve engine of 100 H.P. is also connected), two alternate-current machines, which work in parallel and have an output of 60 amperes at 2200 volts; the current is conveyed by a concentric cable of ·1 square inch (62 square millimetres) section to two sub-stations in Cassel, one situated in the yard of the Mass-house, and the other in a cellar of the School-house. At each of these stations the high-tension current works an alternate-current motor of 75–80 effective H.P., each of these again working two other dynamos as shown in Fig. 34, giving a continuous current at 110 volts to supply the three-wire system. At one of these stations there are two sets of accumulators, charged by the two continuous-current dynamos during the day and supplementing the supply during the time of maximum consumption. The dis-

tribution from the secondary stations is exactly the same as an ordinary three-wire system, the alternate-current motor taking the place of the usual steam engine.

Alternate-current motors are employed, as they need no commutators and with voltages of 2000 allow of better means of insulation than if built for continuous currents. The usual difficulty of starting these motors is met by using the accumulators to bring up their speed to that of the generator before the alternate-current circuit is closed. This system is very suitable for utilizing a small amount of water-power at a distance from the town. The Cassel Station, which has been working since May 15th, 1891, is capable of maintaining 2600 sixteen candle-power lamps burning together, or about 3500 installed ; by erecting more accumulators and increasing the numbers of turbines, the installation would be sufficient to run simultaneously 9000 lamps, or 12,000 installed.

Fig. 35 gives a diagram of the arrangement.

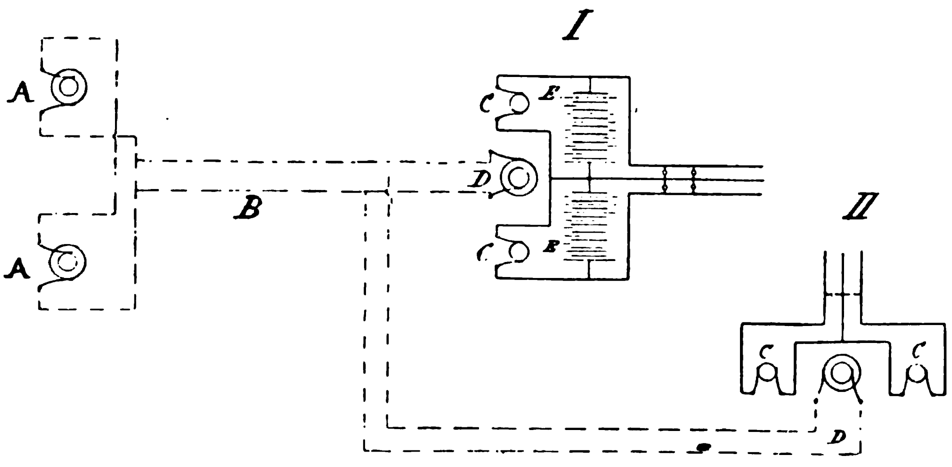


FIG. 35.—DIAGRAM OF SYSTEM USED AT CASSEL.

Primary Station,	A. A.	.	Alternating-current dynamos, 2200 volts × 60 amperes = 180 H.P.
,, ,,	B.	.	Concentric lead-covered cable ·1 square inch (62 square millimetres).
Secondary Station I.,	C. C.	.	Continuous-current dynamos.
,, ,,	D.	.	Alternating-current motor, 80 H.P.
,, ,,	E. E.	.	Accumulators.
,, ,, II.,	C. C.	.	Continuous-current dynamos.
,, ,, ,,	D.	.	Alternating-current motor, 80 H.P.

LAUFFEN—HEILBRONN.

TRANSMISSION OF ELECTRIC LIGHT AND POWER. MULTIPHASE SYSTEM.

The company owning the Lauffen Portland Cement Works obtained a concession for supplying electrical power to Heilbronn, having at Lauffen a water-power from

Plate IV.

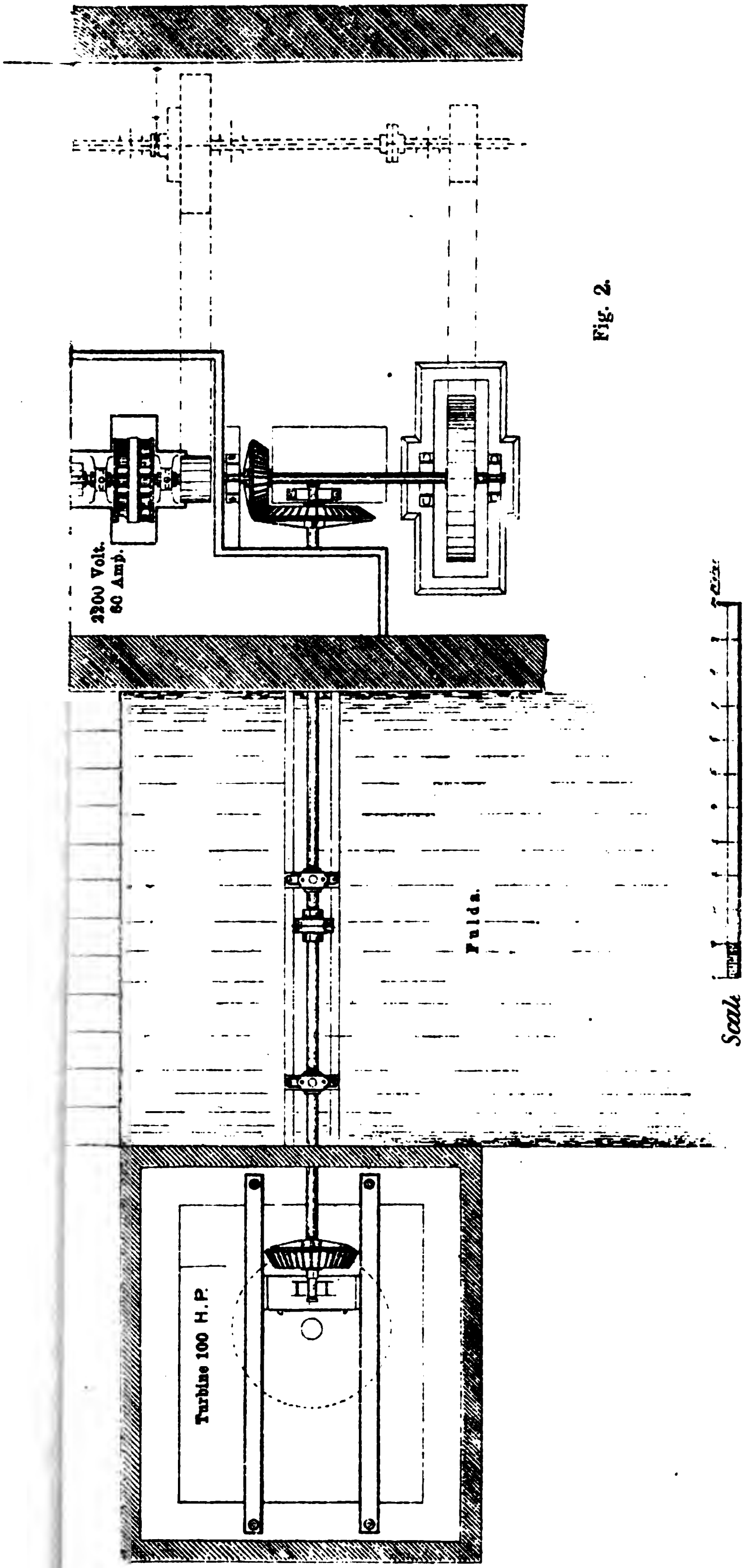


Fig. 2.

the Neckar of about 1500 H.P., at a distance of about seven-and-a-half miles from the town of Heilbronn. Of this water-power 600 H.P. is used for the cement works, leaving 900 H.P. available for the supply of light and power. On account of the distance to which the power had to be transmitted, it was necessary to use alternate currents, and it was decided to adopt the multiphase system with the so-calied rotary currents. Any arrangements for storing power by means of accumulators were unnecessary, as the supply of water for generating power was always sufficient to meet the demands. Plate V. shows the turbine house at Lauffen.

Of the three turbines intended for the electrical works, only one was at first employed, driving a 300 H.P. rotary-current dynamo, giving 4000 amperes at 50 volts, which is transformed to a current of 39 amperes at 5000 volts. It is preferable to employ a transformer to give the necessary potential rather than use a machine giving it direct, as low voltage dynamos are not only easier to insulate, but have a higher working efficiency than very high tension machines, so that the loss of about three per cent. in the transformation is balanced by the higher efficiency of the generating dynamo. The mains from the transformer to the boundary of the town of Heilbronn consist of three bare wires, ·24 inch diameter (6 millimetres), carried overhead on oil insulators, placed on cross bars, as shown in Figs. 36 and 37, the poles being 26 to 46

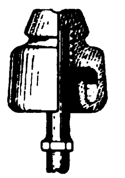


FIG. 36.—OIL INSULATOR.

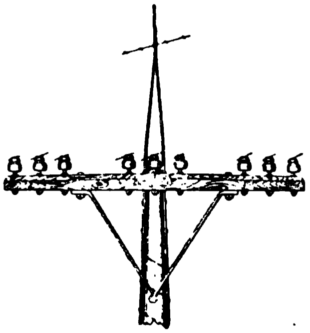


FIG. 37.—POLE WITH OIL INSULATORS.

feet high, so as to be at least a yard above the highest trees along the high-road. Above the mains all along the line is run an ordinary barbed wire, experience having shown this to be the best protection against lightning. The overhead wires end at a main transformer, exactly the same as the one at Lauffen, reducing the voltage from 5000 to 1500. This is considered necessary as the mains are continued in the town underground, for which such a high tension as 5000 volts is unsuitable. At a distance of about 220 yards from this transformer are placed others, for reducing the voltage from 1500 to 100 volts for supplying the houses. The transformers are put under shelter, as shown in Fig. 38. The two upper divisions show the transformers, the lower part having the safety switches and connections to the mains, being so arranged as to be very accessible. The total loss in the seven-and-a-half miles, of leads and in the double transformation is only 20 per cent.; so that of the 200,000 watts generated at Lauffen, 160,000 watts are available for consumers in Heilbronn, being sufficient for 3200 glow lamps of sixteen candle-power, or their

equivalent in arc lamps and motors. As the whole of the supply is never required simultaneously, at least 4200 lamps could be installed.

A second turbine, driving a rotary-current machine, was put up to form a reserve; but during the Frankfort Exhibition it was used for the Lauffen-Frankfort transmis-

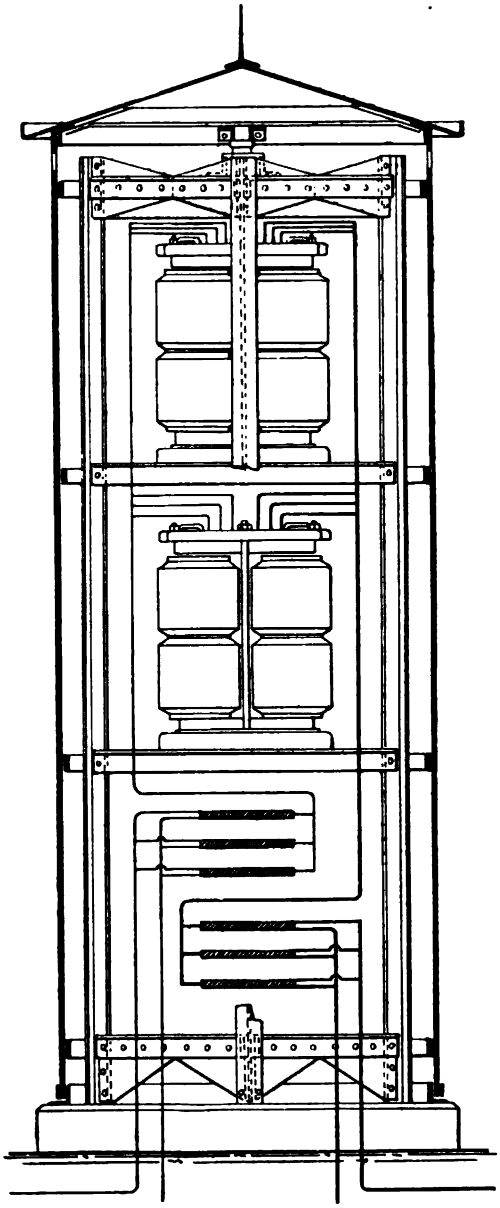


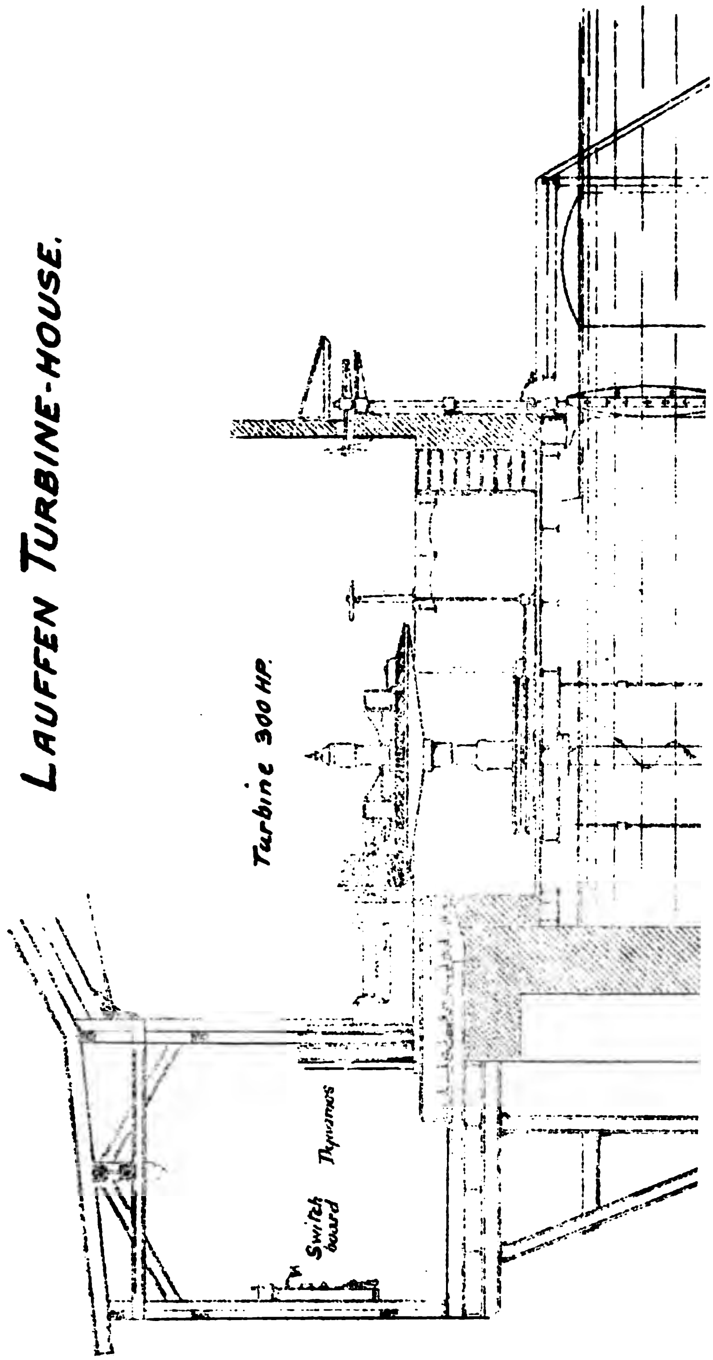
FIG. 38.—TRANSFORMER SHELTERS.

sion experiments, a transformer being employed to raise the voltage to 25,000, instead of 5000 volts, on account of the great distance of about 108 miles (175 kilometres).

A plan of the house containing the generating machinery and the turbines is shown by Fig. 39.

p. 40.

LAUFFEN TURBINE-HOUSE.



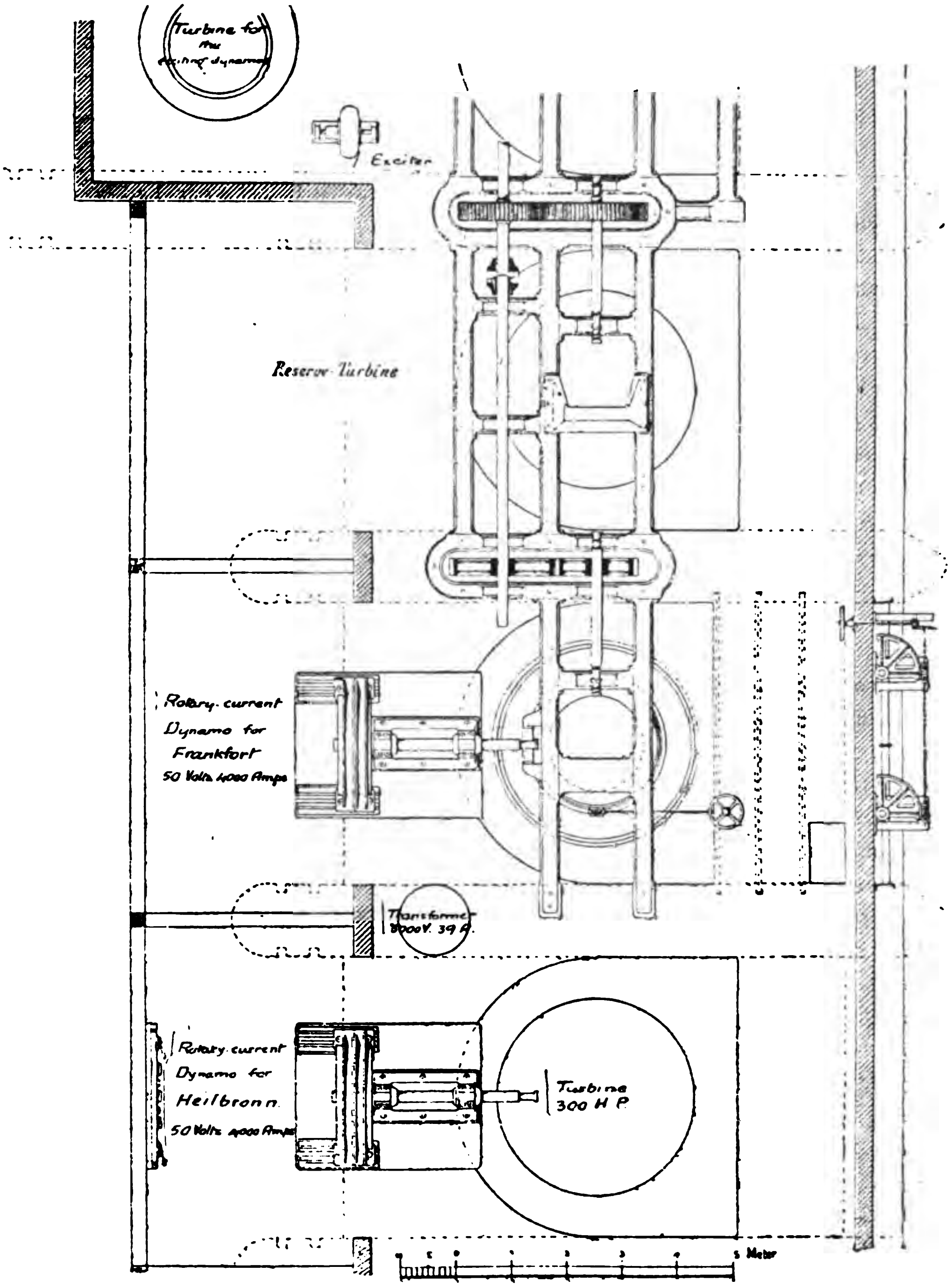


FIG. 39.—PLAN OF MACHINE ROOM, LAUFFEN.

ELECTRIC LIGHTING OF PONTRESINA, SWITZERLAND.

ALTERNATING HIGH-PRESSURE GENERATING STATION TRANSFORMING INTO CONTINUOUS CURRENT—MOTIVE POWER WATER.

By R. Alioth & Co., Basle.

Pontresina, one of the most frequented tourist resorts of Switzerland, situated in Upper Innthal (Engadine), 6000 feet above the sea-level, last year had a central station erected by the firm of R. Alioth & Co., of Basle, which should prove interesting as it forms one of the rather scarce applications of continuous-current transformation.

Pontresina is situated on the valley side of the river Inn, on the Bernina-pass-strasse, which unites Innthal with Veltlin (the watershed of the Danube and Po), and extends 1000 yards out; four miles south from there, where the famous Morteratsch glacier runs into the narrow valley, are found the magnificent falls coming from the high pass of Berninabaches, which are utilized for the works. The water itself is partly collected in a small reservoir, 6600 feet above sea-level, and from thence is laid a cast-iron pipe, 18 inches in diameter at the foot of the mountain and glacier, to the turbine-house. The works are arranged for a pressure of 190 lbs., due to a height of 430 feet, and a flow of water of at least 62 gallons per second; in summer the stream conveys a greater quantity of water.

The general electrical arrangement of the station is at follows:—In the station on the Morteratsch glacier the energy of the water is utilized in turbines to give a high-tension continuous current, which is taken by two wires—primary mains—to a second station in the middle of Pontresina—the transformer station—where it works the continuous-current transformer, which transforms it to a lower tension, which is then applied to the simple two-wire system in the district. Fig. 40 shows a plan of the arrangement. With regard to the equipment, each station is to be provided with four dynamos, of which three have been already erected. The generator dynamos, and primary winding of the transformer are connected in parallel; the secondary winding of the transformer is in parallel with the supply mains.

In the generating station (Fig. 41), the 75 H.P. high-pressure turbines, by Escher Wyss & Co., Zurich, are joined directly, by flexible couplings, with the dynamos of R. Alioth & Co. (Fig. 42). The latter give, at a speed of 500 revolutions per minute, 34 amperes at 1500 volts. These dynamos are run at constant speed, the turbines being provided with automatic speed regulators, so that the transformers of the secondary station in Pontresina also run at approximately the same speed with varying loads; and the regulation of the current can be effected at the latter station, The primary station has, therefore, little to do either with the regulation or with the distribution of the supply. The three machines together give a total production of 34 amperes, at 4500 volts. The primary leads, consisting of copper wire, ·2 inch in diameter, are run overhead on oil insulators in the usual way.

In the transformer station (Fig. 43), the high-tension current is taken to a switch-board, on which are the measuring instruments and safety appliances, and also the connections to the continuous-current transformers. By means of a multiple switch, the number of transformers at work is kept the same as the number of generators,

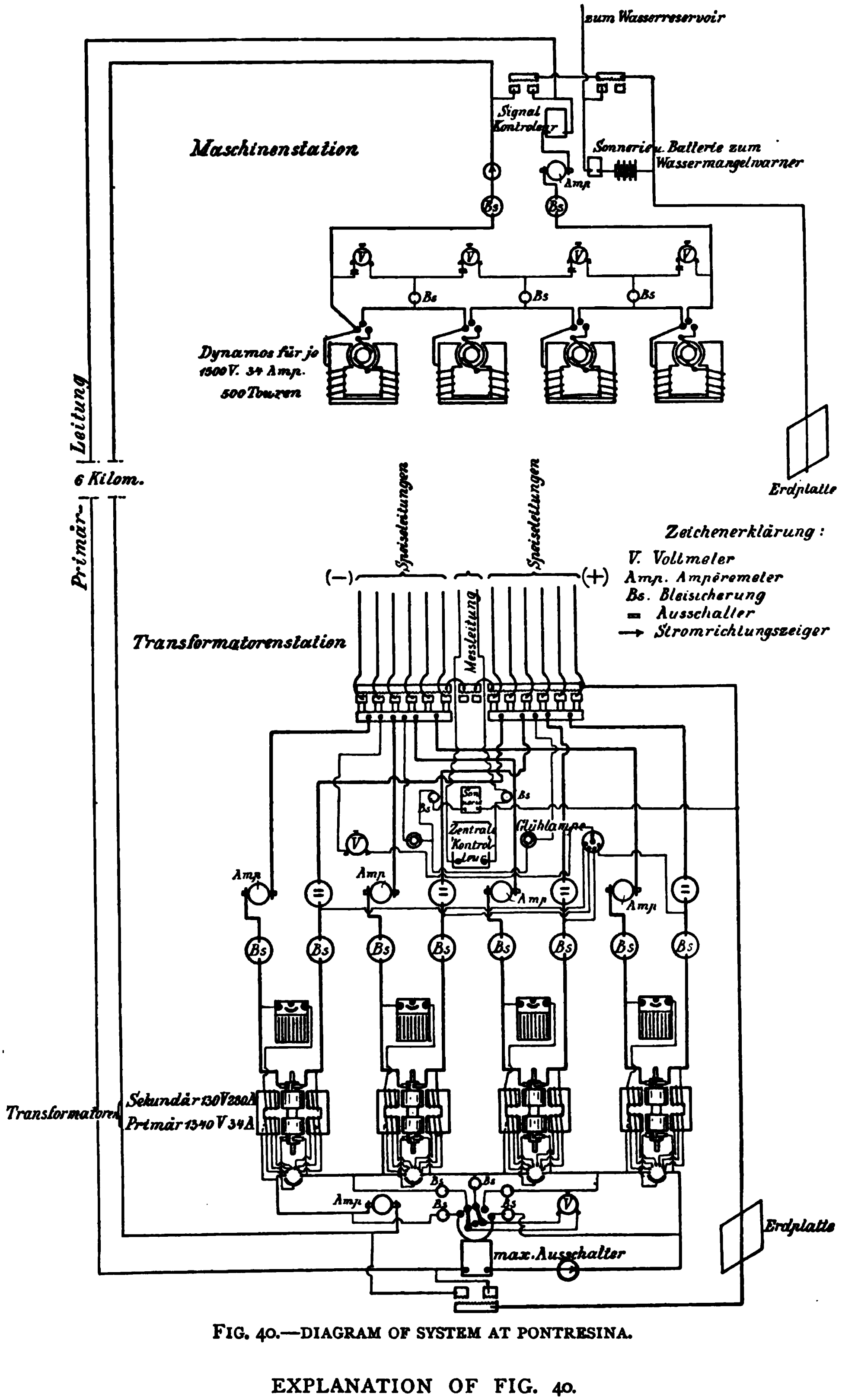


FIG. 40.—DIAGRAM OF SYSTEM AT PONTRESINA.

EXPLANATION OF FIG. 40.

Wasserreservoir	Water reservoir	Speiseleitung	Feeder
Primär Leitung	Primary main	Messleitung	Testing wire
Bleisicherung	Lead fuse	Stromrichtungszeiger	Current direction indication
Ausschalter	Switch	Erdplatte	Earth plate

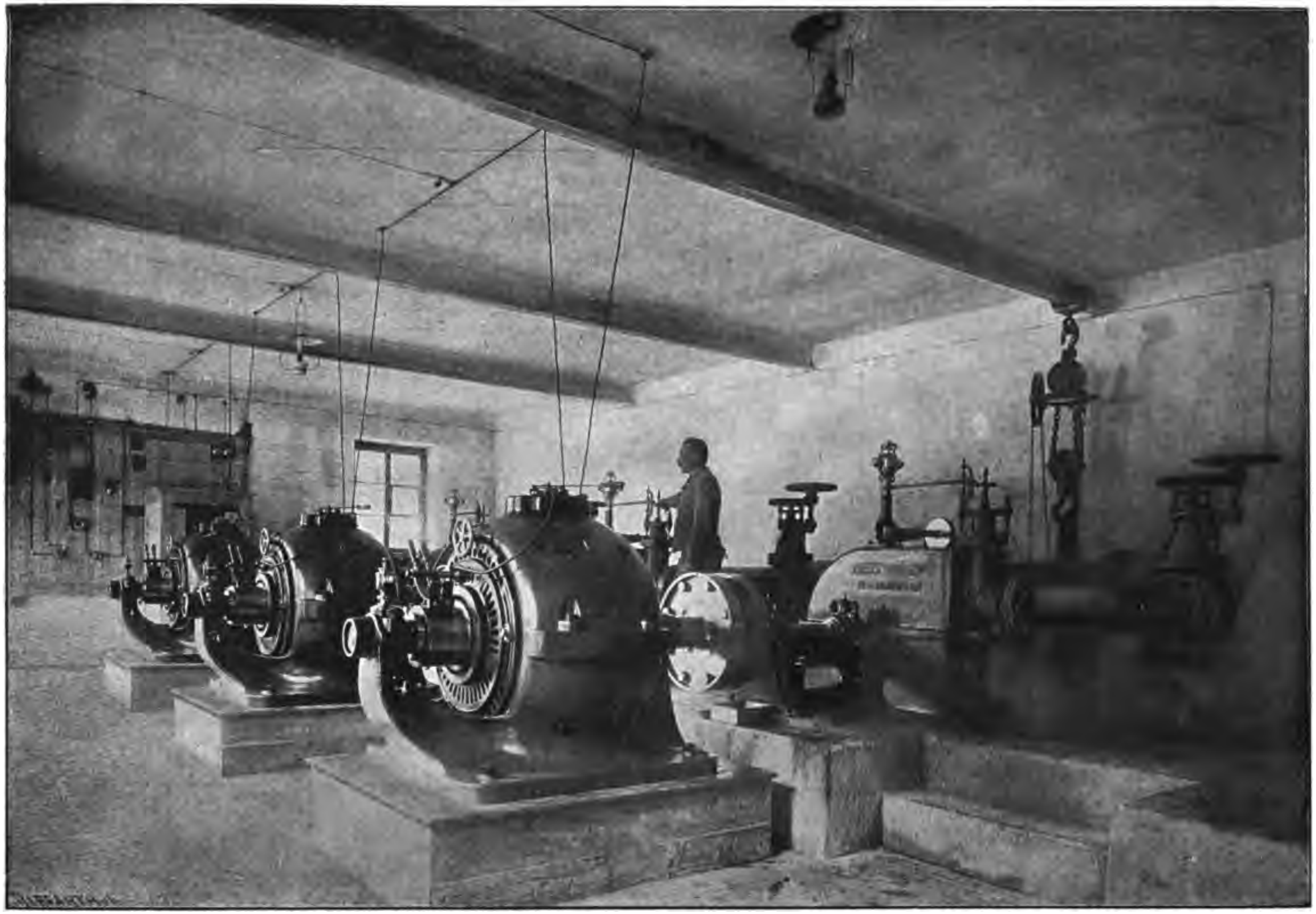


FIG. 41.—ENGINE-ROOM, PONTRESINA.

according as the consumption of current varies. The transformers shown in Figs. 44 and 45, have six-pole field magnets with two drum armatures. The secondary armature gives 280 amperes at 130 volts, and is regulated from a second switch-board in the same way as an ordinary shunt dynamo in direct-current stations. All the necessary instruments for controlling and regulating the secondary currents, and the safety appliances, are connected here. From this switch-board six feeders go to the supply mains, which are of bare wire, and are run overhead. The output, which at present reaches a maximum of 840 amperes at 130 volts, is used for 120

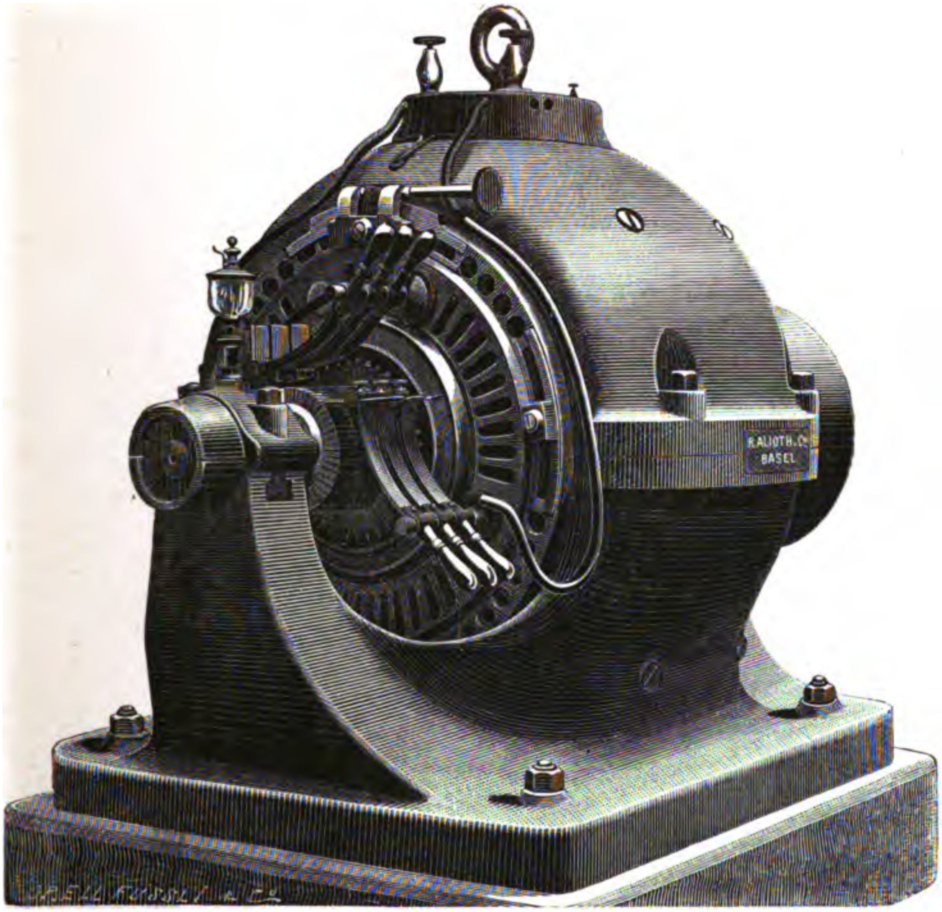


FIG. 42.—PRIMARY DYNAMO.

volt glow lamps. Already 18 arc lamps are connected, and over 1700 glow lamps of various powers, which are used for both street illumination and private lighting; the latter is chiefly for the larger hotels of Pontresina.

The undertaking was converted into a Co-operative Company of Consumers, which each inhabitant of the district can join, and is managed at a small cost. In spite of the great distance between the generating station and consumers' district (four miles), this central station was arranged for direct current, in order to obtain its many advantages, the principal one being safety. The business of the electric supply company is expected to increase greatly as soon as there is a demand for power, to be furnished by means of small motors.

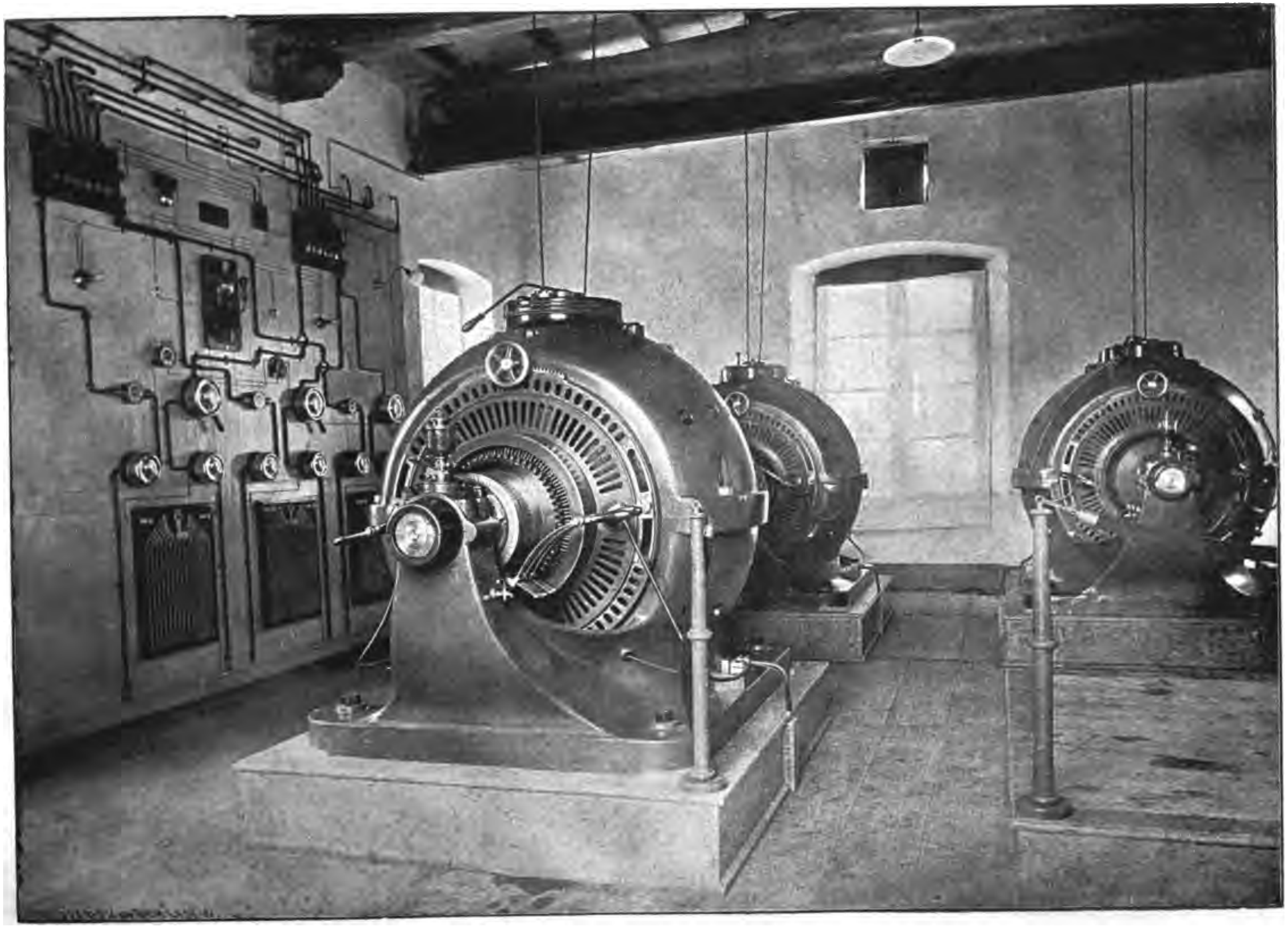


FIG. 43.—TRANSFORMER STATION, PONTRESINA.

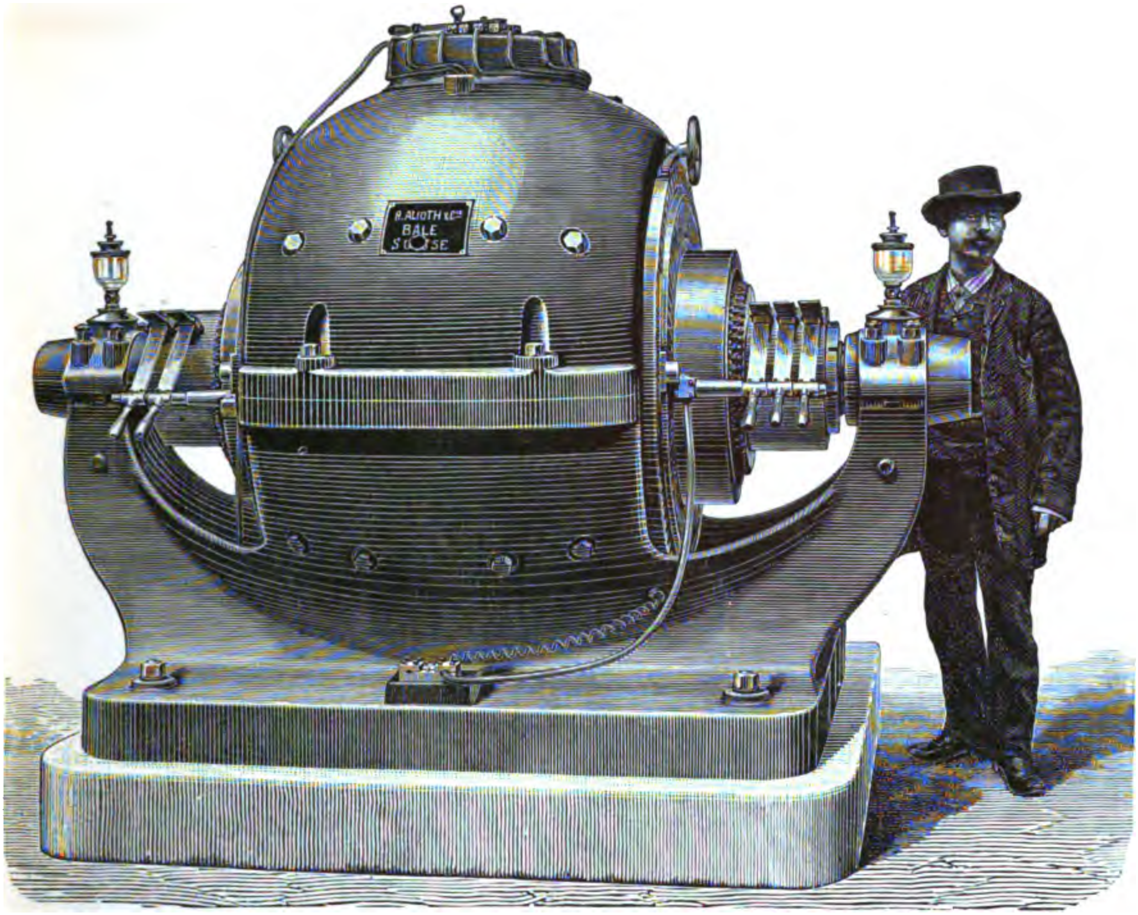


FIG. 44.—TRANSFORMER.

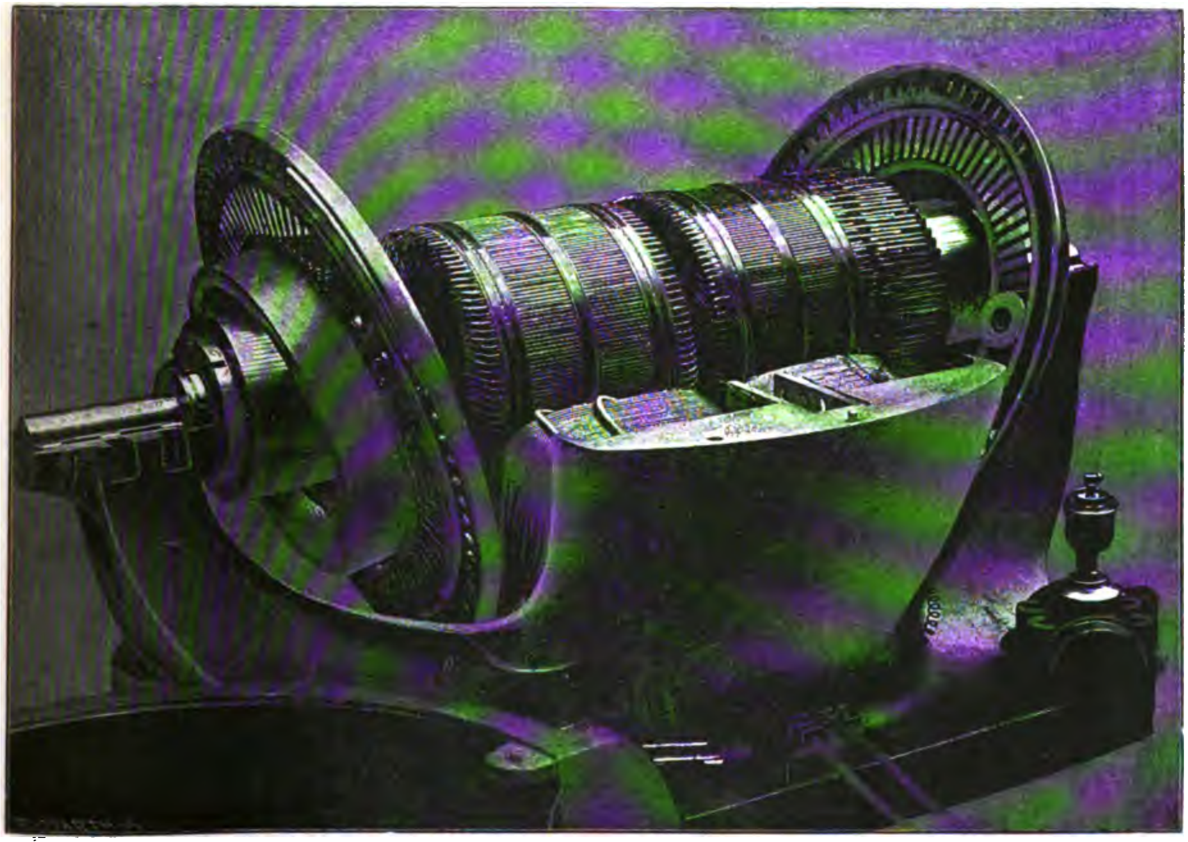


FIG. 45.—TRANSFORMER.

THE COLOGNE AND DÜSSELDORF MUNICIPAL CENTRAL LIGHTING STATIONS.

ALTERNATING-CURRENT DISTRIBUTION BY THE HELIOS COMPANY.

The Cologne central station, of which the accompanying illustration (Fig. 45 (*a*)), shows a section, is situated at the side of the Municipal Gas and Waterworks, and is, in fact, under the same administration. This is a good plan—saving, as it does, the expense of a separate administrative staff, and utilizing the supply of steam to the

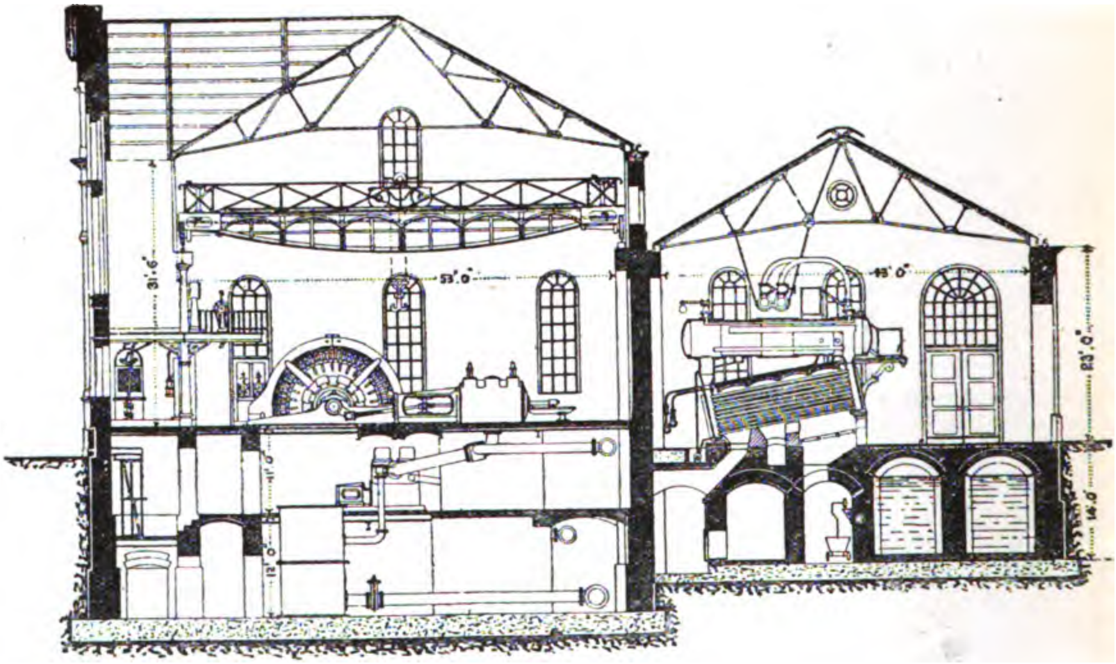


FIG. 45 (*a*).—SECTIONAL ELEVATION, COLOGNE STATION.

engines of the electric central station from the boilers of the Waterworks during the hours of light load.

The boiler-house, which is 152 ft. long and 43 ft. across, contains five pairs of Steinmüller boilers, each of 1650 square feet heating surface, and working at a pressure of 114 lbs. per square inch. Below each ashpit there is a shoot running to a tunnel, in which are small trucks, which, after being filled with the ashes, may be run out into the yard. The engine-room is the same length, but 53ft. broad and considerably higher. It contains, at present, two 600 H.P. Sulzer compound condensing engines, and one 125 H.P. Sulzer engine, also compound, and provided with a condenser. These engines, the shafts of which carry the hubs of the magnet-wheel of the alternators, run at 85 revolutions, requiring, therefore, 72-pole

alternators to give 50 complete cycles per second. The spindles of the magnet-wheels also carry the ring armature of an eight-poled exciter, the field-magnets of which are attached to the stationary armature of the alternator by means of four cast-iron arms. These arms and the spindle are, in fact, the only cast-iron parts of these dynamos, if we leave out of view the large ring-shaped frame to which the armature coils of the alternator are attached in the well-known Zipernowsky manner. The field-magnets of the exciters, although ring-shaped and containing eight radial polar projections, are wholly built up of iron sheets, half a millimetre (·02 inch) thick, and of half-ring shape, the polar projections being cut out by means of boring and slotting machines, after the whole of the field has been first screwed and then riveted together. The weight of iron in the exciter armature is nearly 1 ton 2 cwt. for the 600 H.P. dynamo, and about 14 cwt. for the 125 H.P. dynamo. The weights of copper are respectively about 6½ cwt. and 4½ cwt. upon the armatures, and 13 cwt. and 9¼ cwt. upon the field magnets of the exciters; these are shunt-wound for the 125 H.P. dynamo and compound for the large dynamos. In spite of the low speed these dynamos have an electrical efficiency of 93 and 89 per cent. respectively, and a commercial efficiency of 90 and 85 per cent., including the exciter. In Fig. 45 (*a*) a 25-ton travelling crane is also shown. This crane can travel through the whole length of the engine-room. The magnet-wheel of the alternator and the armature of the exciter, which is attached to the former, can be moved laterally so far that the parts of each may be easily got at, this lateral movement being made by means of sliding bars and a hand-wheel.

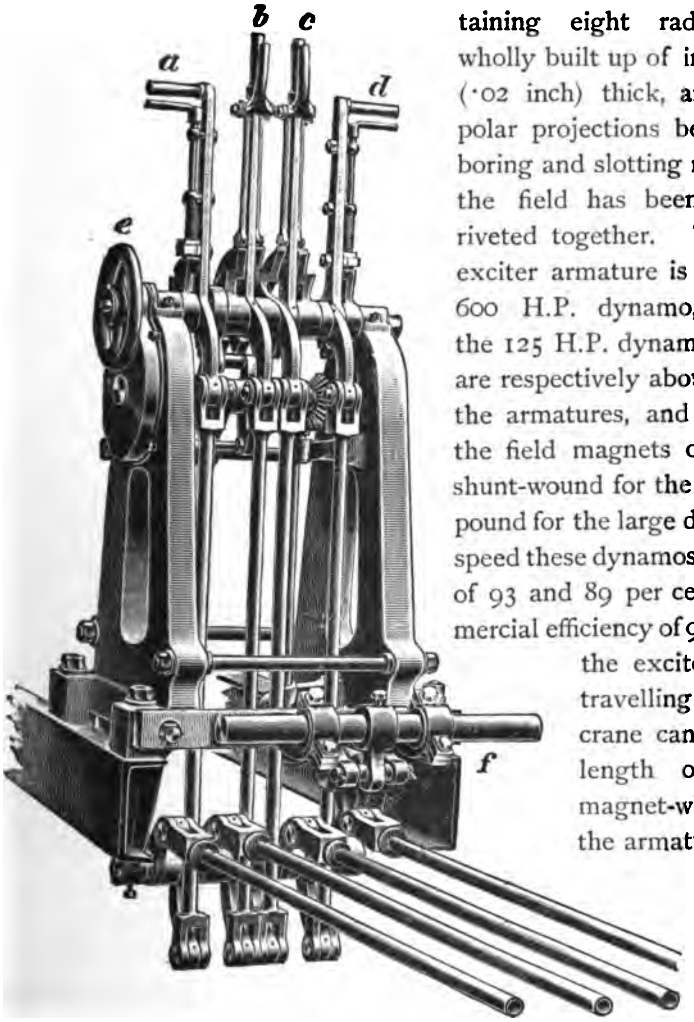


FIG. 46 (*a*).—SWITCHING MECHANISM FOR ALTERNATORS.

The principal novelty of this station is the extreme simplicity of handling all these dynamos, combined with the want of all visible connections which could annoy the mind of the mechanical engineer. This central station is not a labyrinth of hundreds of bare or insulated conductors, but rather a simple looking machine station, the control and regulation of which is effected by a simple mechanism moving a couple of levers.

These lever mechanisms, of which Fig. 46 (*a*) is an elevation, are due to Herr

Carl Coerper, the managing director of the Helios Company of Cologne, which erected this station.

The method of introducing one alternator into the circuit to work in parallel with one already running is as follows :—" Lifting the handle of the bolt (Fig. 46 (*a*)), we move the lever *d* until the bolt fits into the first hole. We have in this way completed the field circuit of an exciter. We now proceed to regulate the excitation by slowly moving the second lever *c*. The field having attained a suitable degree of excitation, we close the main circuit of the exciter, *i.e.*, the field of the alternator, by moving lever *d* to the last notch of the sector. Then by taking resistance out of the field circuit of the alternator by moving lever *b*, we excite it to its normal pressure. So far, no damage could have been done if any of the levers had been handled wrongly or in the wrong order. To avoid any damage being done by an inattentive man, a locking device is employed which renders it impossible to introduce the dynamo directly into the lamp circuit. By moving lever *a* to the first slot in its disc, we complete the circuit of the load of resistances, and we must now turn the wheel *e* before we can go on with our lever. By doing so we introduce more and more resistance, and only now can we move *a* to the next position, when this resistance and the lamp-circuit are in parallel. We then have to turn *e* backwards, and after having wholly taken out the resistance load, we move the lever to its last position, when the dynamos will be working in parallel with the others upon the town circuit."

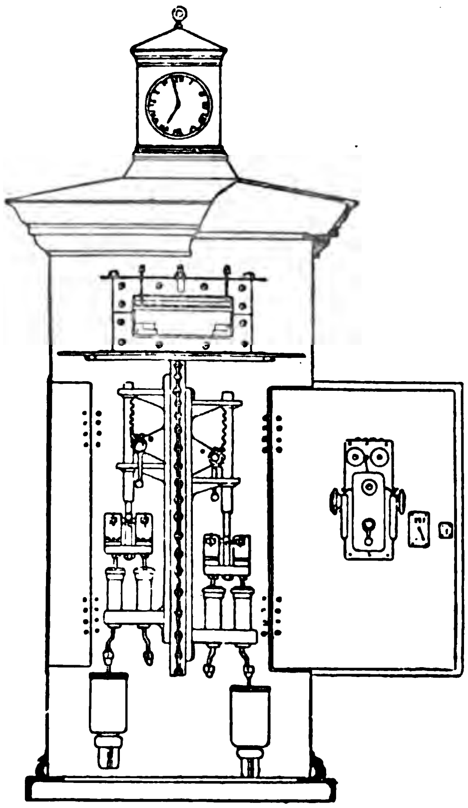


FIG. 47 (*a*).—DISCONNECTING COLUMN.

One must mention the fourteen "disconnecting columns," by means of which any part of the whole network may be disconnected, thus allowing new portions of cable to be joined or new house junctions to be made, which is necessary as there is no secondary network at all in this town. Fig. 47 (*a*) shows one of these columns designed for use at Amsterdam, containing four mercury switches and cable ends, an alternating-current clock, and a small telephone station, which allows of communication between these " disconnecting columns " and the central station. For this purpose about three-and-a-half miles of telephone cable have been put down with the eleven miles of concentric cable. The columns adopted at Cologne are minus the clock.

The cables are placed in wooden troughs, in which they are supported by iron hooks, the troughs are filled with molten asphalt and then covered with a layer of

bricks and sand. The cables, which were furnished by the Société d'Exploitation des Câbles Électriques (Système Berthoud, Borel et Cie.), of Cortaillod, Switzerland, are, moreover, protected by lead and iron sheathing. Each length of 200 to 300 yards has been tested at double the working pressure, namely, to 5,000 volts, between the two conductors, and between the exterior conductor and the lead cover. The insulation resistance of the whole network, measured with 100 volts and a mirror galvanometer, was found to be 1,000 megohms per mile.

The supply network is calculated for a maximum output of 20,000 16 candle-power lamps, burning simultaneously. The first portion of the plant, comprising two 500-600 H.P. dynamos, and one of 125 H.P., will, however, soon be too small. Since the opening of the station at the commencement of September, 200 house connections have been made, and about 100 transformers have been installed, the total primary

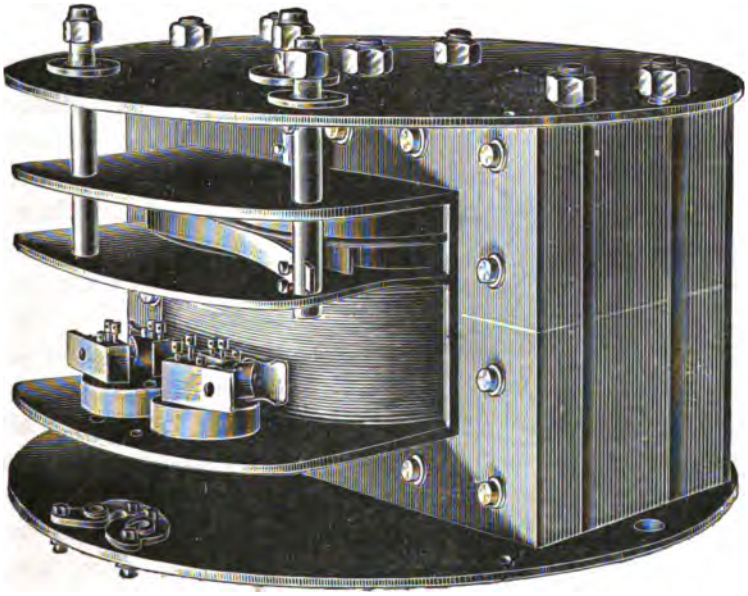


FIG. 48 (*a*).—10 KILOWATT HELIOS TRANSFORMER.

current being at present about 45 amperes, equal to about 1,600 lamps burning, and nearly 6,000 installed ; and this number will certainly be greatly increased. The transformers (Fig. 48 (*a*))—which contain three secondary terminals, with a potential difference of 36 volts between an exterior and the middle terminal, or 72 volts between the two exterior ones—have been built for this low pressure to avoid great losses in the resistances for arc lamps, the Helios Company having succeeded in turning out an alternate-current arc lamp giving a white and steady light, and running off 36 volts, including resistance. For this reason the three-wire system is employed in most cases of house-wiring for the arc lamp leads, two wires being in use for the incandescent lamps. The terminals of the transformer are put out of the reach of private persons by means of a metal case, not shown in the figure, which represents a 10-kilowatt transformer. This size is generally used for large houses, or cases where two or three small houses are joined to one transformer.

The electric meter (Fig. 49 (*a*)) adopted is the Bláthy. The shunt field, on account of its high self-induction, reaches maximum magnetization about a quarter of a period after the main field, and when at zero magnetization produces powerful eddy currents in a rotating aluminium disc. This eddy current moves in such a direction that it is attracted by the main field, which, at this time, possesses maximum magnetization. When, on the other hand, the main field equals zero, it produces an eddy current in another part of the disc, which is displaced from the point where the shunt field eddy currents are generated by a quarter of the disc's circumference, the main field eddy current being besides in such a direction that repulsion takes place between it and the shunt field, which is very strong at this instant. A continuous rotation therefore takes place. The Committee which tested the Bláthy meter about one year ago at Frankfort found that it started with one 100-volt 16 candle-power lamp, that is, with 0·5 ampere, and that its rotation continued to be proportional within three per cent. throughout its range, that is, from less than one ampere up to 100.

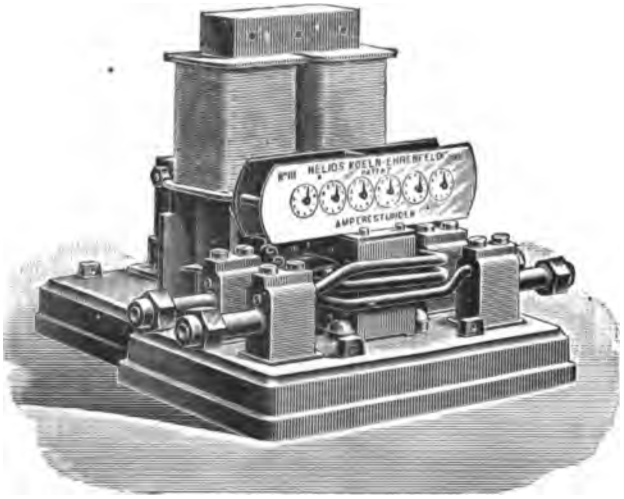


FIG. 49 (*a*).—BLÁTHY ALTERNATE METER, WITH CASE REMOVED.

As to the central station's rules for house-wiring, the principal points are the following:—The working pressure is 72 volts, and the wiring has to be carried out on the assumption of one ampere being required for each 16 candle-power lamp, and of a loss of one volt from the transformer terminals to the last lamp, when all the lamps installed are burning. This allows 20 candle-power lamps to be inserted instead of 16 candle-power lamps, without passing the limit of one volt loss. Of course, this results in somewhat stout leads, and it is not necessary to limit the maximum current density to two amperes per square millimetre (1,300 amperes per square inch) as for long leads, this load can never be attained with a loss of only one volt. The insulation resistance of the whole installation has to be 1/c of a megohm, C standing for the current required by the respective installation. No wire is to be placed below a ceiling or a floor, unless lead-covered, and iron-armoured concentric cables are employed for this purpose. The smallest safety fuse must melt at six amperes, and all fuses have to be double poled. For testing the installation before connection to the network, the consumer has to pay about 1*s*. per lamp up to 50 lamps; from 50 up to 500 lamps the sum decreases rapidly, since for 500 lamps £8 6*s*. (166 marks) has to be paid. Transformers and meters, as well as the short end of primary cable from the network into the cellar of the consumer's house, are the property of the municipality. For the meter there is the same annual payment as for gas meters, that is 10*s*. to 20*s*.

For every lamp installed, be it arc or incandescent lamp, the consumer has to guarantee a mean annual utilization of 300 hours. The price charged is 8 pfennings per 100 watt-hours (9½*d.* per Board of Trade unit). To large consumers there is, of course, a rebate. The largest consumer, except the theatre, which is not yet connected to the station, will perhaps be the old "Gürzenich," where over 800 lamps are to be installed by the Helios Company.

ELECTRIC LIGHTING OF STUTTGART.

HIGH-TENSION ALTERNATING CURRENTS PRODUCED PARTLY BY WATER AND PARTLY BY AUXILIARY STEAM POWER, AND DISTRIBUTED IN THE TOWN OF STUTTGART.

BY C. & E. FEIN.

The Neckar, in its course from Esslingen to Heilbronn, is remarkable for a great number of falls, which although utilized for the working of factories and mills, are still not altogether taken advantage of. One of the latest schemes is that proposed by the firm of C. & E. Fein for the transmission of electrical energy to Stuttgart, for the distribution of light and power within the town. The proposal of this firm, which is worked out and designed as shown in the annexed plans and drawings, Plates VI., VII. and VIII., is to transmit 1000 H.P. obtained from the water power at Hochberg, on the Neckar, about 13 kilometres from Stuttgart.

To supplement the water power and to act as a reserve, in the town of Stuttgart, in the vicinity of the Goods Station, a steam engine of 500 H.P. has been erected, which will work in conjunction with the water power, a storage reservoir having yet to be made ; when that is done, the supply of the town with electric current can be accomplished, so that there will be sufficient power to supply all the demands nightly, and during the day there will be a surplus amount for electromotors.

At Hochberg, the situation of which is shown in Fig. 46, there are 4 turbines of 250 H.P., each coupled direct to a self-regulating alternate-current machine, the arrangement being shown in Plate VI. These machines generate a current at 200 volts, which is transformed up to 5000 volts and transmitted by three suitable mains to the station in Stuttgart. Here the current is transformed down to 600 volts and works in conjunction with the supply of electricity from the steam-engine installation, which is generated at the same pressure.

There are two compound condensing engines, 250 H.P. each, with regulating expansion slide-valves, which are coupled direct to alternating dynamos, the arrangement of which is shown in the plan of the buildings in Plate VII. After the current has, as shown, been brought down to a potential not dangerous to life, it is conducted to the town by underground cables, which are laid in three circles, with a balancing

main as a feeder to connect each. From this network, at any point in the town, a current at 600 volts can be obtained and without danger taken into the houses for direct application, and, when required, can be transformed down to any required electromotive force. A representation of the arrangement is shown in Plate VIII., Fig. 4. This current, as already stated, can be employed not only for lighting, but with special advantages for motors, as in the evening the demands for power decrease to a very great extent, as the consumption for lighting increases. It is found that during the day the greater part of the total energy generated at both stations is used by electromotors, and that during the evening the turbines alone are sufficient to maintain the power for the lighting, and the steam engines have only to work during the occasional interruptions at the water-power station. For this reason only a limited number of lamps can be maintained with certainty, but important extensions are to be made in connection with the steam power.

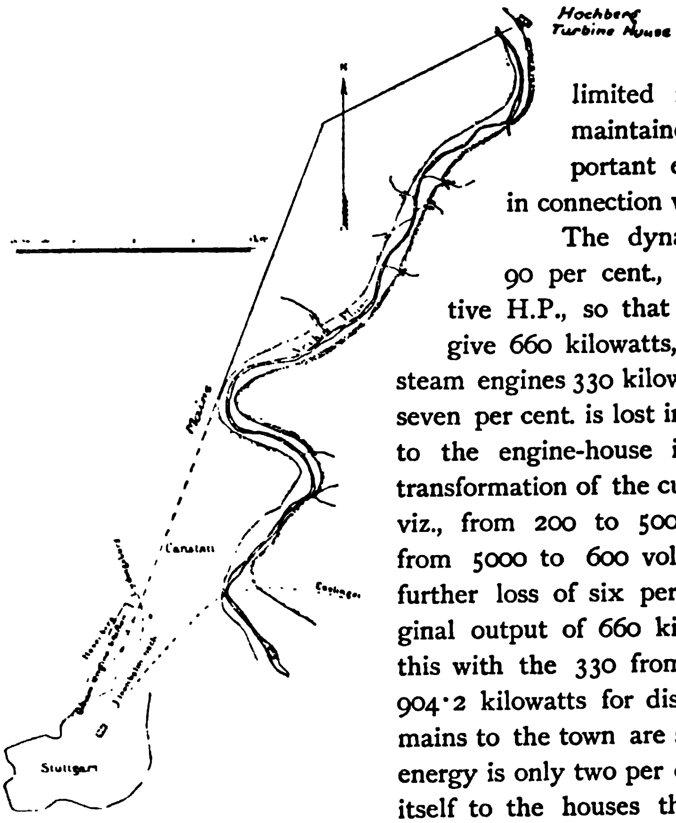


FIG. 46.—PLAN OF HOCHBERG-STUTTGART SYSTEM.

The dynamos give an efficiency of 90 per cent., about 660 watts per effective H.P., so that 1000 H.P. at the turbines give 660 kilowatts, and the 500 H.P. of the steam engines 330 kilowatts. Of the 660 kilowatts, seven per cent. is lost in the leads from Hochberg to the engine-house in Stuttgart. The double transformation of the current in the transformers—viz., from 200 to 5000 volts at Hochberg, and from 5000 to 600 volts at Stuttgart, involves a further loss of six per cent., so that of the original output of 660 kilowatts, 574·2 remain, and this with the 330 from the steam engines allows 904·2 kilowatts for distribution to the town. The mains to the town are so arranged that the loss of energy is only two per cent., and from the network itself to the houses the greatest fall is four per cent., being in the centre of the district only two per cent. Including the loss of three per cent. in the house transformers, which reduces the current from 600 to 100 or any other required voltage, the amount of power available for use is 841 kilowatts or 1145 H.P.; but the working efficiency with small motors is on the average only 80 per cent., and therefore 880 watts are required per brake H.P., so that the actual energy usefully available in the houses is 955 brake H.P. Nevertheless, motors, of such number and size can be used, that this production may be increased by a third, as, with the experience which has since been obtained with small motors and also with gas engines, it has been found that at the most they are required for working

CENTRALSTATION IN HOCHBERG.

C. & E. FEIN. – STUTTGART.

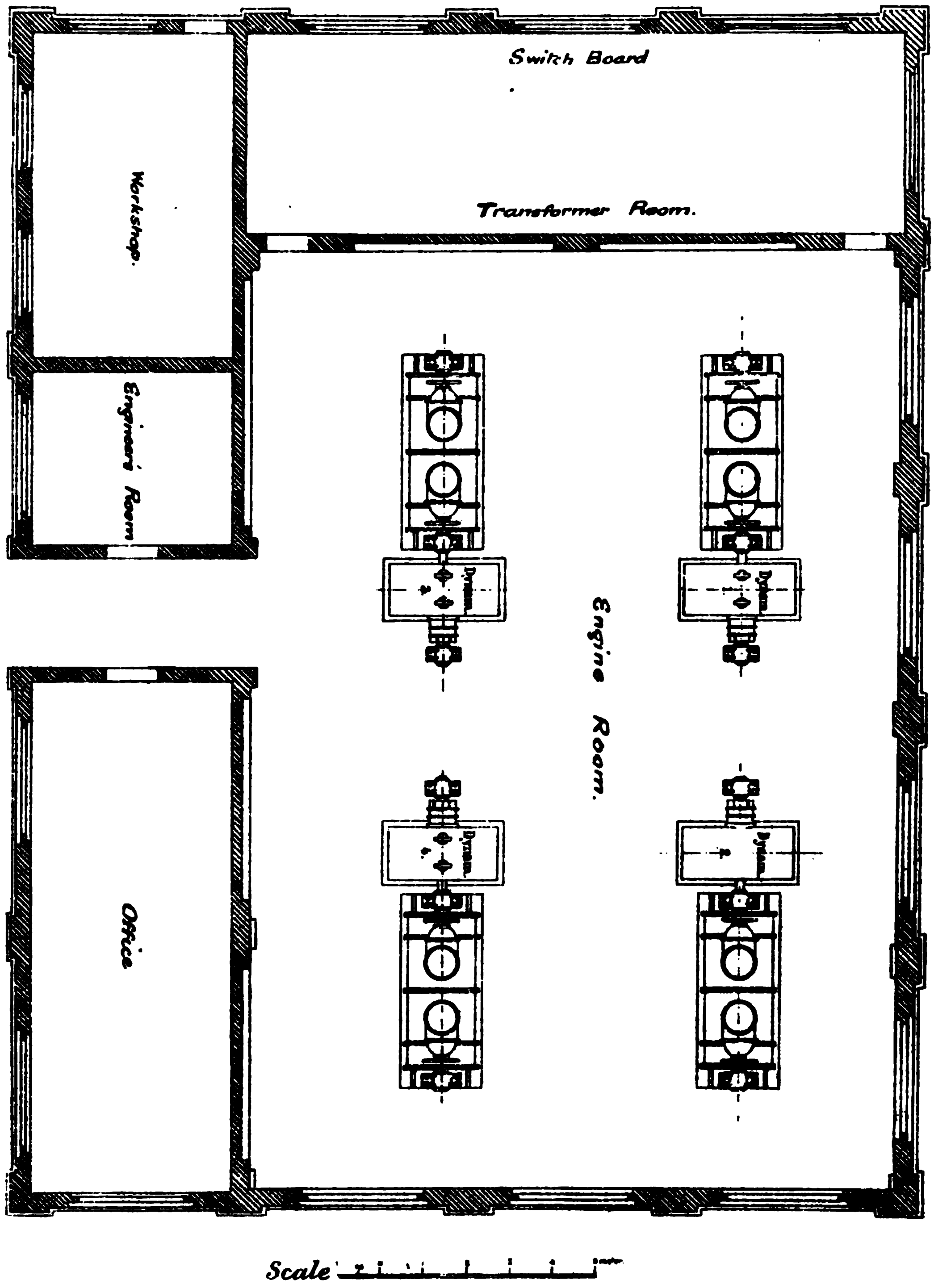
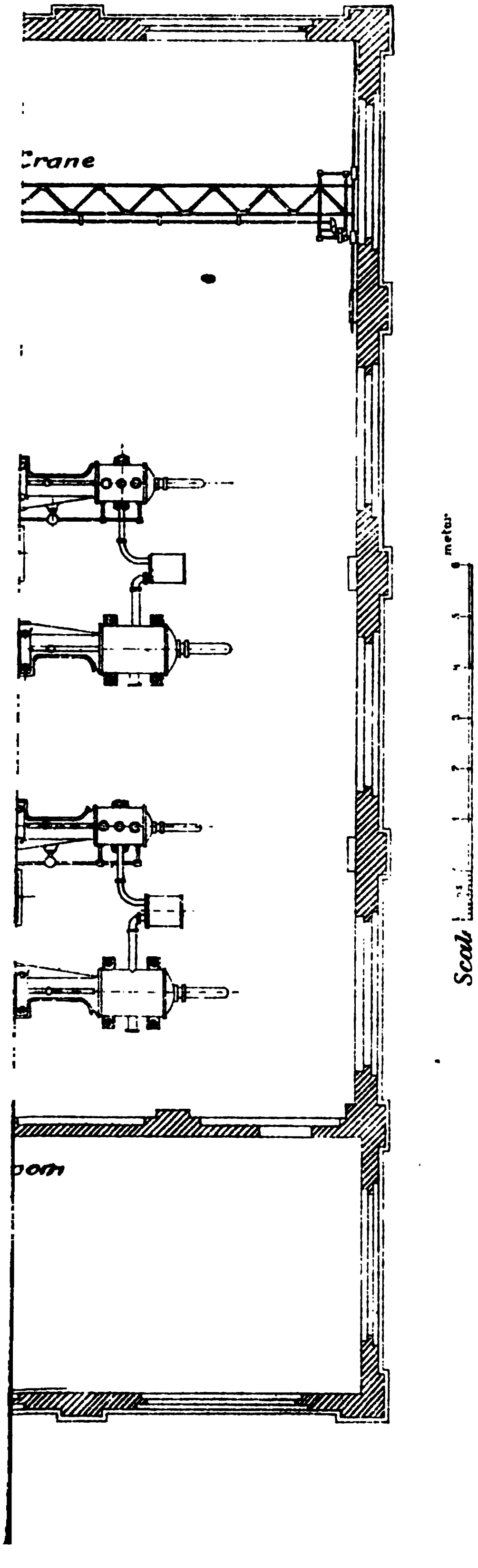
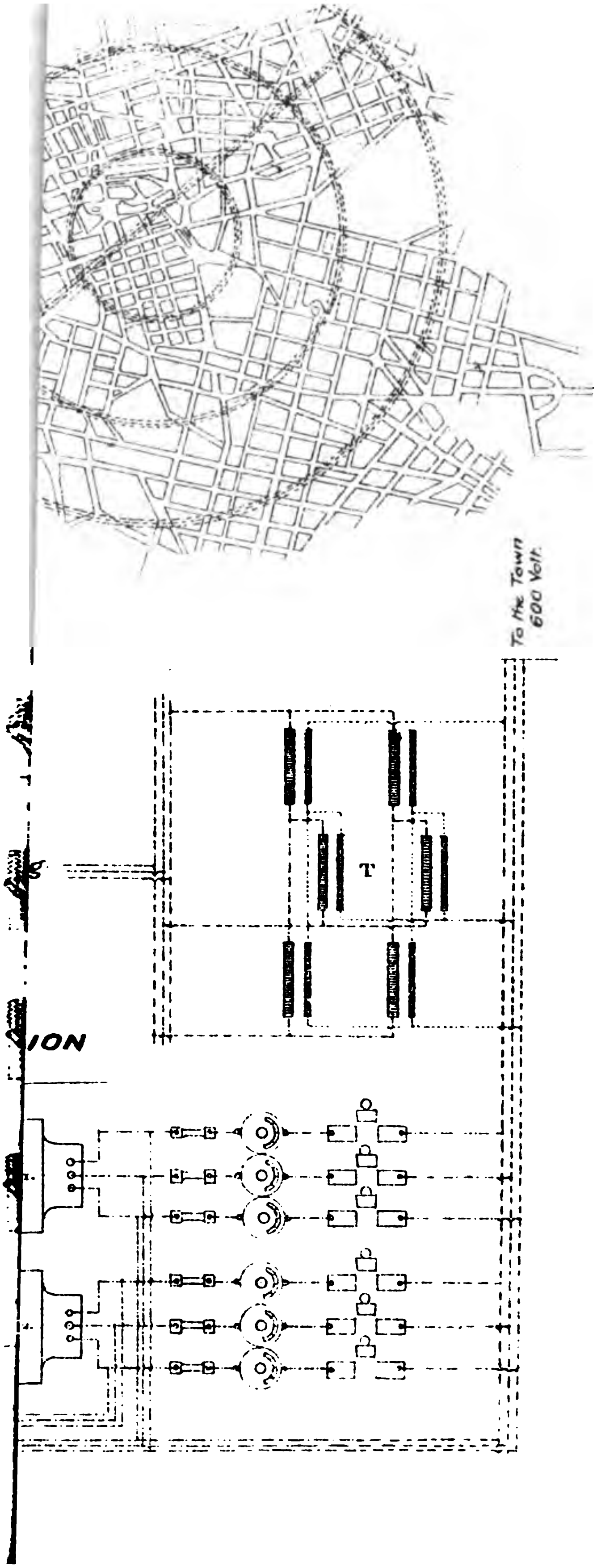


Plate VII.




To the Town
600 Volt.
T
ION

only two-thirds of the whole time. Under these circumstances, electromotors can be installed of a total power of 1273 H.P.

The extent of the lighting has, as already shown, been limited to the amount of available power of about 500 H.P., which, after allowing for the losses in mains and transformers, leaves 308 kilowatts; so that when required, on account of floods and during other interruptions of the turbine, the lighting can be managed entirely by the steam engine. This amount of 308 kilowatts is sufficient for 6160 16 candle-power lamps, taking 50 watts each, burning simultaneously; so that the number installed may be a third more, or 8210. Experience has shown that town lighting may generally be divided in the proportion of three parts for glow lamps to one part for arc lamps; so that the above supply may be taken as being for 6160 glow lamps, and 100 arcs of 1500 candle-power (each requiring power equivalent to ten glow lamps), and 210 arcs of 600 candle-power (each equivalent to five glow lamps).

Figs. 5 and 6, Plate VIII., show diagrams of the two stations.

In the following table of cost the output is reckoned in kilowatt hours, and the current per hour.

EXPENDITURE FOR THE ELECTRICAL WORKS.

		£
1.	Canal and dam work	37,500
2.	Turbine-house, iron-roofed shed, etc., 6,300 square feet space	3,500
3.	Four turbines, of 250 H.P. each, for 11·5 feet head of water, including erection	3,000
4.	Engine and boiler house, with 10,600 square feet building space, including chimney	4,500
5.	Two compound condensing engines (250 H.P. each) with valve-gear, including erection	3,500
6.	Tubular boilers, of 2,000 square feet heating surface each	2,250
7.	One ditto in reserve	750
8.	Electrical machinery, including transformers and apparatus	11,000
9.	Overhead wires from Hochberg to Stuttgart, including poles, insulators, fixing, etc.	5,250
10.	Underground mains from the Stuttgart Station to the town, including laying and part of the conduits	6,500
11.	Network of conductors within the town, including house connections, laying, and part of the conduits	22,100
12.	Preliminary work and supervision of buildings, etc.	2,650
		£102,500

COST OF WORKING.

(*a*) INTEREST AND DEPRECIATION ON CAPITAL.

			£	s.
1.	2 per cent. off the cost of buildings		910	0
2.	8 " " "	turbines	240	0
3.	10 " " "	engines, boilers, electrical machinery and apparatus	1,750	0
4.	5 " " "	leads from Hochberg to Stuttgart	262	10
5.	3 " " "	cables	858	0
6.	5 " on expenses		132	10
7.	4 " interest on total expenditure		4,100	0
			£8,253	0

COST OF WORKING—*continued.*

(*b*) Cost of Management.

	£
1. One manager	250
2. One chief mechanic	150
3. One electrician	125
4. Two mechanics	150
5. Two smiths	130
6. Two stokers	120
7. Two turbine attendants	120
8. Two workmen	90
	£1,135

(*c*) Coal Consumption, Oiling and Cleaning Materials, including Repairs.

	£
1. 900 tons of coal for 1,800 working hours of the 500 H.P. engine at 24*s*. per ton	1,080
2. Oil and cleaning materials for steam engines and turbines	150
3. Repairs for the whole installation	1,470
	£2,700

(*d*) Total Expenses.

	£
1. Distribution and management	325
2. Office expenses, insurance, etc.	460
3. Amount owing to the town	5,000
	£5,785

SUMMARY OF TOTAL ACCOUNT.

	£.
(*a*) Interest and depreciation	8,253
(*b*) Management	1,135
(*c*) Coal, oil and cleaning materials and repairs	2,700
(*d*) Expenses and debt	5,785
	£17,873

II.—ANNUAL ELECTRICAL OUTPUT.

Output of the Complete Station for Motors and Lighting.

	Kilowatt hours.
1. 1273 H.P. for motors, 6 hours per day, 300 working days per year	2,016,432
2. 6160 16 c. p. glow lamps, 700 hours	215,600
3. 100 arc lamps, 1500 c. p., 2500 hours	125,000
4. 210 " " 600 " " "	131,250
	2,488,282

The yearly output of 2,488,282 Board of Trade units therefore costs £17,873, so that one Board of Trade unit costs 1·73*d*.

The price of 1 H.P. hour for motors is $\cdot 88 \times 1\cdot 73 = 1\cdot 52d.$

Taking into consideration the cost of the additional house connections, also transformers and electrical meters, which would be from £4 to £10 per H.P. according to their size, and reckoning 14 per cent. for interest and depreciation, the total cost per H.P. hour would be from 1·62*d.* to 1·74*d.*

A 50-watt glow lamp costs $1\cdot 73d. \times \cdot 05 = \cdot 086d.$ Including interest and depreciation (14 per cent.) on the cost of house connections, transformers and meters, from 20*s.* to 30*s.* per lamp, and allowing 500 hours as the time of burning per year, would add ·084*d.* to the cost and ·036*d.* for lamp renewals, making a total of ·2*d.* per lamp hour.

An arc lamp of 1500 candle-power costs for current $1\cdot 73 \times \cdot 5 = \cdot 86d.$, carbons, ·66*d.*, interest and depreciation as before ·2*d.*; total, 1·72*d.* per hour. An arc lamp of 600 candle-power under the same conditions costs 1·14*d.*

TEMESVAR.—HUNGARY.

THE MULTIPLE-SERIES SYSTEM.

Before concluding the description of the high-tension system, a few remarks on the Temesvar installation may not be out of place, as the plan of working the electric lights in multiple series forms, as it were, a connecting link between high and low tension. This method of using high-tension currents has, after a long trial at Brighton and other English towns, been abandoned for the transformer system; and it is curious to find that, in spite of the great advance in Austria, a town in Hungary remains lighted on the plan originally started in 1884.

A twenty-four years' concession was given to the International Electric Company, the plant remaining their property at the expiration of the term, subject to purchase by the municipality at their own valuation. The public lighting is stipulated to be effected by means of 731 glow lamps of the intensity of 16 candle-power; but the option is given to the company of switching out a fixed proportion of these lamps at 11.30 P.M., or of leaving the whole number in operation with their light intensity reduced from 16 to 8 candle-power from 11.30 P.M. till dawn. The total number of lighting-hours per annum is 3,597½ for the lamps which are in operation from dusk until dawn, and 1,816 for those which are extinguished at 11.30 P.M. The price fixed in the concession for public lighting is 1·5 kreutzer per 16 candle-power lamp per hour, equal to 53 florins 95 kreutzers per lamp per annum of 3,597½ hours, or 27 florins 24 kreutzers per lamp per annum of 1,816 hours. The company has found it more convenient to exercise the option reserved to it, of keeping all the 731 lamps in operation from dusk till dawn, reducing their light intensity to 8 candles after 11.30 P.M.; and the municipality has agreed to pay a round sum of 29,000 florins (£2,416 13*s.* 4*d.*) per annum for this lighting, and 41·95 florins (£3 10*s.*) per annum for

each additional lamp worked in the same way. Comparing these figures with what precedes, it will be found that the electric lighting of the streets now in operation costs 2,520 florins more than it did on the former plan of combined lighting, partly by gas and partly by petroleum. On the other hand, the streets are lighted throughout with 16 candle-power lamps from dusk until 11.30 P.M., and with 8 candle-power lamps from 11.30 P.M. until dawn. For electric light supplied to private consumers the concession fixes the price at 1·81 kreutzers per 16 candle-power lamp per hour, or 0·1131 kreutzer per candle per hour, with the right to charge 15 per cent. more for lamps of less intensity than 16 candles. In all these prices, the renewal by the company of lamps failing from legitimate wear is included.

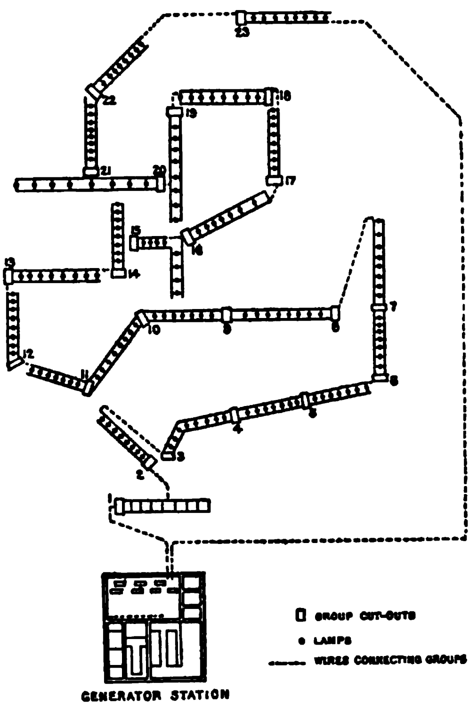


FIG. 47.—MULTIPLE-SERIES SYSTEM—TEMESVAR.

One central generating station has been provided for the whole town, from which at present four distinct circuits have been laid, each fed by a separate dynamo. The street lamps are connected up in "multiple series," that is to say, in groups placed in series on the circuit, the lamps in each group being connected up in parallel.

Fig. 47 shows the arrangement diagrammatically. Each group consists of eight lamps in parallel; at present three of the circuits have twenty-four groups in series, and the fourth circuit has twenty-three groups in series, giving a total of ninety-five groups, comprising 760 lamps, of which 731 are public lamps and 29 are used at the central station. To meet the risk of interruption in any circuit through the failure of individual lamps, an automatic switch is arranged so as to put in a reserve lamp in the event of a whole group being interrupted. Another self-acting device will short-circuit the whole group, so that the other groups in the circuit will be unaffected. The automatic lamp-switch is contained, together with the reserve lamp, in the lantern, and the automatic group cut-out consists simply of an electro-magnet with a coil of high resistance connected up in parallel with the group of lamps it protects. These appliances have been found to work well. The main conductors are formed of insulated single copper wire, 4·6 millimetres (·18 inch) in diameter; they are carried overhead on porcelain insulators, fixed to telegraph posts or to wooden arms let into the walls of houses. The resistance of this conductor is about 1·8 ohm per mile. The glow lamps are placed in reflectors at an angle of about 45° from the vertical, and are carried on brackets either fixed to the walls or on

* This switch has been recently abandoned.—K. H.

special cast-iron posts. Fig. 48 shows the details of street bracket and reflector, with automatic lamp-switch and lamps in place. The brackets are, for the most part, fixed to the walls of houses or to painted wooden posts. The under side of the reflector, which is made of enamelled iron disposed in the form of a flat inverted cone, reflects the upward rays from the lamp and causes the extreme ones to strike the ground at a distance of about 50 metres from the foot of the lamp-post. The increase of lighting effect in the streets due to those reflectors is very marked. The upper part of the reflector serves the purpose of a case and weather protector for the automatic lamp-switch, which is inserted from the top, and the lower end of which is fitted with copper hooks, to which the two lamps are fixed. The glow lamps are fitted with holders of a type designed by the engineer, which provide the lamp terminals with large and strong eyes affording considerable contact surface and adapted for hooking on direct to 2·5 mm. (1 inch) copper wire, the ends of which have merely to be bent into a suitable form for maintaining the lamp in any required position. The glow lamps are of an improved Lane-Fox type, manufactured by the Electric Company at their works in Vienna. Although originally intended for 16 candle-power lamps they have so far been worked at 18 candle-power, taking 53·6 volts and about 1·18 amperes, which is equivalent to 3·52 watts per candle-power, or about 211 candles per horse-power. The current is maintained at 10 amperes, and the potential between independent groups of lamps is 53·6 volts. The aggregate energy lost in overcoming the resistance of the main leads, switches and cut-outs, is 12·8 per cent. of the total electrical energy generated at the central station—a very satisfactory result on a system of over 37 miles of streets. The electromotive force in the conductors is about 1,400 volts, which is below the normal capacity of a Brush machine, thus allowing more lamps to be operated from the four machines. The machinery is driven by a 300 horse-power horizontal compound-condensing tandem steam-engine, running at the normal speed of 100 revolutions per minute. During the first 1,200 hours of lighting, only three lamps out of 760 failed, and one of these had been broken maliciously. Although the system at Temesvar has more complicated arrangements than are now required if secondary generators are used, it has shown that it is quite practicable to light all the streets in a town by electricity; also it has enabled a comparison to be made between the useful effect obtainable from arc and from glow lamps. Each group of glow lamps was found to absorb practically the same energy as one arc lamp of from 800 to 1,000 candle-power,

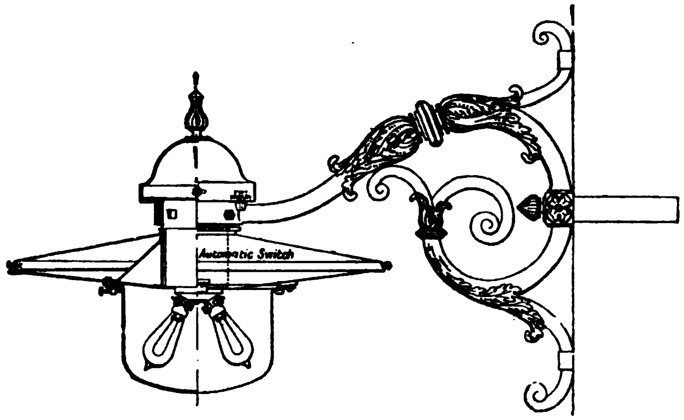


FIG. 48.—LAMP BRACKET.

and ninety-one or ninety-two of these could have been run with the same expenditure of power as 731 glow lamps. The eight glow lamps forming one group are in many cases scattered in different streets, often quite out of sight of each other. Under such circumstances, the substitution of one light centre, however powerful, for every eight could only be done by leaving many spots in complete darkness. To give a usefully diffused light by means of arc lamps, their number would have to be considerably greater than ninety-two, or, in other words, the standard of street lighting would have to be raised, and for this the town was not prepared to pay.

The business has now passed into the hands of the Brush Electrical Engineering Company of London, who have extended the installation by placing alternating-current dynamos at the station to work transformers for the supply of houses, so as to utilize the original plant for street lighting only, as, even with the advanced knowledge of the present day, it is doubtful whether for this purpose a more economical system could be employed.

THE FERRANTI SYSTEM.

The Ferranti high-tension alternating system is installed in the following Continental Electric Light Stations:—

Barcelona, 3 Alternators. Capacity, 9000 lamps.

Municipal	Stations,	Paris	3	Alternators.	Capacity	9000	lamps.
"	"	Nancy	3	"	"	"	"
"	"	Havre	2	"	"	12000	"
"	"	Melun	2	"	"	6000	"
"	"	Troyes	2	"	"	6000	"
"	"	Dijon	1	"	"	3000	"
"	"	Lens	1	"	"	3000	"
"	"	St. Ceré	1	"	"	600	"

M. Ferranti has designed the complete equipment for central stations, which include his dynamo, exciter, transformer, automatic regulator switches and concentric mains. This system is exclusively employed by the London Electric Supply Corporation at their central station, Deptford. Particulars will be found in the "Engineer," Vol. LXVII., pp. 286, 293, 311, 524.

THE MADRID STATION OF THE ELECTRICITY SUPPLY COMPANY OF SPAIN.*

ON THE LOWRIE-HALL ALTERNATING SYSTEM WITH TRANSFORMERS.

The interior arrangement of the station is clearly shown by Fig. 48 (*a*), which is taken from a photograph. Direct transmission from the engine is not used, and the alternating dynamos and their exciters are driven by belting. The multipolar dynamos are similar to those used for the Kensington Central Station, and by Messrs. Lowrie and Parker. The speed is 350 revolutions per minute; the mean speed at which the armature conductor is passed by the field magnets is about 6000 feet per minute, and the number of alternations 10,000, 5000 complete phases per minute, producing an electromotive force of 2000 volts. The pressure of the current is regulated by means of the thermal effect of a wire, rigidly attached at its extremities and weighted at the centre; the sag formed then in the wire by the central weight, when the wire is expanded by the heat generated by the passage of the current, gives a very efficient and sensitive motion.

The current is taken to a switch-board, on which are a number of units, consisting of plug switches, arranged as well as their corresponding terminals in the form of a rectangle, so that any number of generators and circuits can be electrically connected by adding the requisite number of unit switch-blocks. When it is desired to couple together the machines in parallel, the two dynamos are run as nearly as possible at the same speed, and when their phases synchronize (as indicated by the pilot lamp) they are switched together by the plugging of the corresponding switch so as to combine four unit blocks together as a square. The transformers, which are placed in the houses, change the electromotive force or pressure from 2000 to 100 volts; the current is charged for by meters of the Lowrie-Hall† type, which resemble the Edison more than any other, but differ in principle in that the alternating current which passes through the meter does not deposit metal from one plate to the other. This is done by a secondary battery, which is put in series with a depositing cell containing plates which are gradually changed in weight by the battery just as if the alternating current did not exist. To guard against currents of unauthorized pressure‡ entering the houses, a simple apparatus known as an Electric Safety-Valve, designed by Killingworth Hedges and Lowrie-Hall, is exclusively employed. A glass tube, partially exhausted, is fitted with two springs which are prevented from actual contact by a small strip of paper; one of these springs is connected to one of the house wires, and the other to the earth. At the working current of

* For particulars of the system, *see* the "Electrical Review," vol. xxiv., page 179.

† Professor Forbes on Electric Meters. Transactions of the Society of Arts, 1888.

‡ See Board of Trade Rule, page 198.

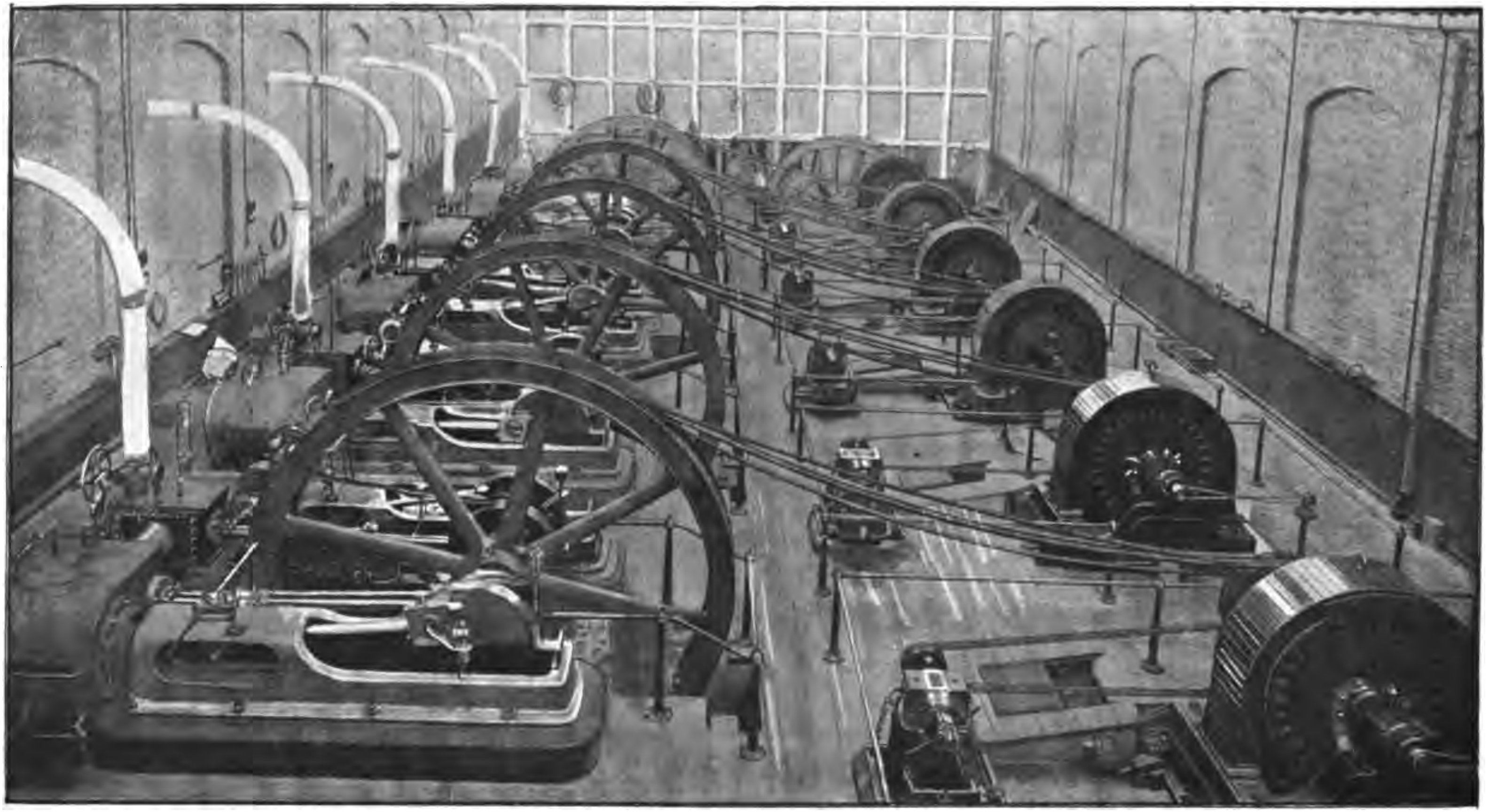


FIG. 48 (*a*).—ENGINE ROOM, MADRID STATION.

100 volts there would be no contact through the paper, but should a pressure of over 300 volts be reached the paper is perforated, and the springs coming together form direct communication with earth ; the sudden decrease of resistance blows the main fuses, and prevents that circuit being used until the fault is repaired. At present there are about 18,100 lamps at Madrid ; the price charged is 1*s.* 0*d.* per unit, the price for gas being 9*s.* 4*d.* per 1000 feet. According to the *Revista Minera*, the cost of lighting by electricity is cheaper than either by petroleum or gas. The comparative cost of these illuminants, both in Madrid and London, is given in the following :—

Petroleum :—Madrid, 85 centimos per litre, or say 5*d.* per pint ; London, 16 centimos per litre, 1*d.* per pint.

Gas :—Madrid, 40 centimos per cubic metre, or, say, 9*s.* 4*d.* per 1000 cubic feet ; London, 13 centimos per cubic metre, 2*s.* 9*d.* per 1000 cubic feet.

PART II.

LOW-PRESSURE DISTRIBUTION BY CONTINUOUS CURRENTS, EITHER DIRECT OR IN CONJUNCTION WITH SECONDARY BATTERIES.

INSTALLATIONS AT HAMBURG HARBOUR, BREMEN HARBOUR, LUBECK, HAMBURG, BARMEN, HANOVER, AND DUSSELDORF, AND ACCOUNT OF MULTIPHASE SYSTEM.

By Schuckert & Co., Nuremberg.

For the supply of towns with electric current, in Germany, as in other countries, various systems have been proposed and carried out; the installations, either with alternating or direct current, can be classified as follows:—

1. Alternating currents direct from the machine.
2. „ „ with transformers.
3. Continuous currents direct.
4. „ „ with secondary batteries.
5. „ „ „ transformers, with or without secondary batteries.
6. Continuous currents, transformed from alternating currents, with or without the employment of transformers or secondary batteries.

In choosing between alternating and continuous current, the prominent advantage of the former is the facility it affords for distributing to great distances with mains of small size, and without having extreme loss of energy, the dynamo being used to generate current at a low voltage, which is transformed up in order to secure economy in the mains and afterwards transformed down in the district of the consumers. On the other hand, this system has the disadvantage, compared with continuous currents, that when employed for motive power the motors used need special appliances and will not stand overloading. With a direct-current system, on the contrary, the motors may be worked above their normal load, which is specially important when they are employed to drive small machinery, and their regulation is easily effected by means of a variable resistance; also, the addition of secondary batteries to a direct, current system ensures the greatest possible simplicity of working. Obviously, the choice between the two methods of supply, with alternating or continuous currents, must be decided according to the circumstances and requirements of each case.

Shortly after the introduction of the incandescent lamp, the question arose as to the best means of supplying separate consumers from a central station. The first method suggested was, naturally, to have a pair of wires going to each consumer; a great improvement was then made, so as to reduce the cost of copper, by employing feeders connecting the station to certain points in the distributing network where the demand for current was greatest. In this case the fall of potential in the feeders is

immaterial, the voltage being kept constant at the distributing points, whilst the loss in the supply mains can be limited to about 1·5 volts. This forms the principle of the system employed at the present time, in the applications to be described.

THE THREE-WIRE SYSTEM.

An improvement was made in the distributing systems by the adoption of the three-wire system, first suggested by Dr. Hopkinson. In this method two dynamos are run in series, connected to a pair of mains with a third balancing wire.* The lamps are connected between this balancing wire and the two outside mains, so that the system is really one of double the voltage of a two-wire system; the middle wire, having to carry only the difference between the loads on the two sides, can therefore be of small section. On this system the stations at Barmen, Neapel, Verona, Berchtesgaden, Malmö, etc., have been laid down. At Lubeck, Hamburg, and Bremen, the two-wire systems at first employed were changed to this also.

The arrangement can be extended to the use of four or five mains, it being a question, however, whether the saving in copper is balanced by the necessary complications of machinery and apparatus. Probably the best methods for distributing to a considerable distance are by means of continuous-current transformers in conjunction with accumulators or by using alternating or rotary currents.

ELECTRIC LIGHTING OF THE HAMBURG HARBOUR DISTRICT.

About 5000 glow lamps of 16 candle-power are required for lighting the district, which comprises the offices and warehouses, the Custom House buildings, etc., as well as 33 arc lamps (12 ampere); for these arc lamps a separate plant was employed to work them in series, their scattered positions requiring this for the sake of economy in the conductors. The machinery consists of six glow-lamp dynamos, 360,000 watts, and six arc-light dynamos, 36,000 watts total load, being driven by three steam engines of 138 H.P., and one of 50 H.P. The larger of these are compound condensing engines supplied by the Sächsischen Maschinenfabrik of Chemnitz, diameters of

*For diagram, *see* p. 111.

cylinders 16 in. and 24 in., stroke 32 in., giving 138 brake H.P. at 100 revolutions per minute, with steam pressure of 90 lbs. and cut-off $\frac{1}{4}$. By increasing the cut-off, the power could be raised to 224 H.P. The small horizontal steam engine has a cylinder diameter of 14·4 in., stroke 28·8 in., and gives 55 brake H.P. at 90 revolutions per minute, with a steam pressure of 90 lbs. and a cut-off of $\frac{1}{4}$.

The dynamos are of Schuckert's flat-ring type (with horizontal magnets), and are coupled direct to the steam engines.

The switch-board is placed at one side of the machine-room, close to the glow-lamp dynamos. Besides the usual switches, fuses, measuring instruments, main switch for the arc-lamp circuit, may be mentioned the automatic potential regulator, which, besides compensating for the varying losses in the mains due to changes in the consumption, also provides for any variations in the speed of the engines which may

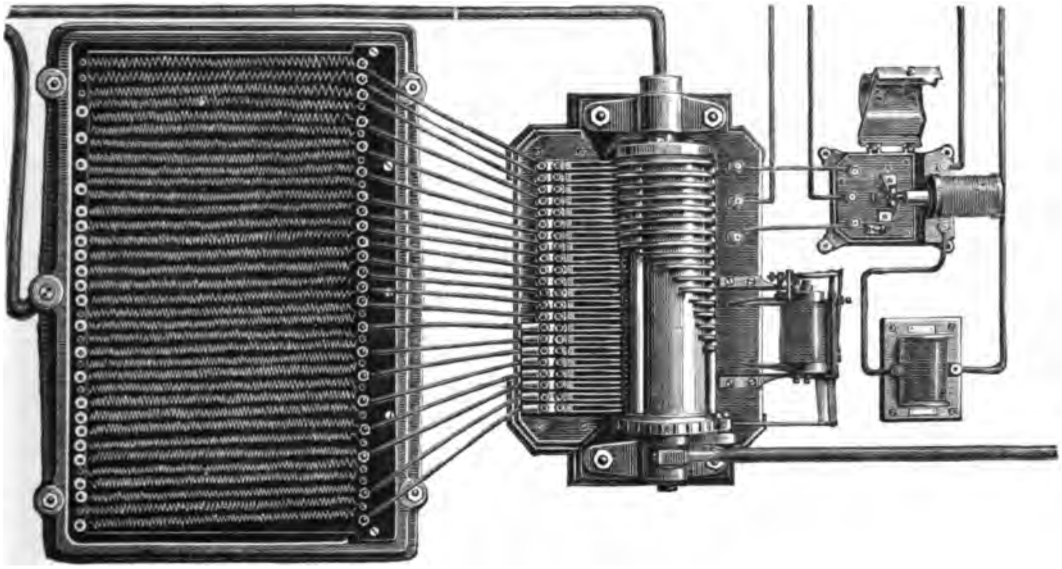


FIG. 49.—AUTOMATIC POTENTIAL REGULATOR.

occur with different loads. This regulator, as shown in Fig. 49, consists of resistances with a row of contacts, which are put in and out of circuit under the control of a sensitive relay, the sparking being reduced to a minimum. For each of the main circuits a regulator is provided (there being 15 in all); these are all worked from a small shaft which is itself run from the main shafting, and is therefore always at work whenever the machines are running.

The two-wire system of mains is employed, as having the advantage of great simplicity in construction and management compared with a three-wire system, the latter, however, being used for the most distant buildings. To supply the glow lamps there are 15 main circuits; the length of the mains, including the return wire, varies from 100 yards to 770 yards; the maximum fall of potential at full load is 12 volts, the lamps being worked at 103 volts.

Fig. 50 shows a plan of the district lighted; the lead-covered cables are laid in iron troughs,

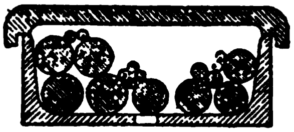


FIG. 51.—CABLE CONDUIT.

with iron covers shown in Fig. 51; also the 33 arc lamps are supplied by lead cables laid in the same way, in three circuits.

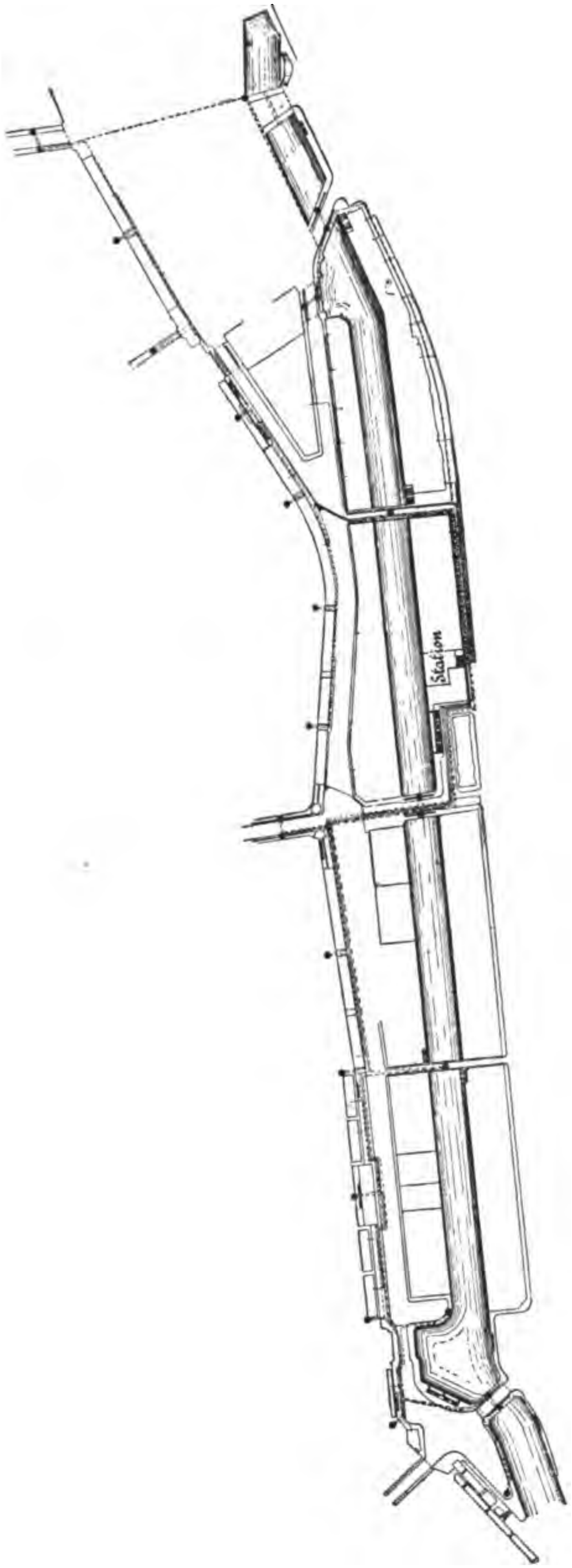


FIG. 50.—PLAN OF HAMBURG HARBOUR DISTRICT.

ELECTRIC LIGHTING OF THE BREMEN HARBOUR DISTRICT.

This installation was provided for maintaining 2000 16 candle-power lamps (for the port-house, restaurants, offices and buildings on the quays, etc.) and 80 12-ampere arc lamps (for the open spaces, locomotive sheds, engine and boiler house, etc.).

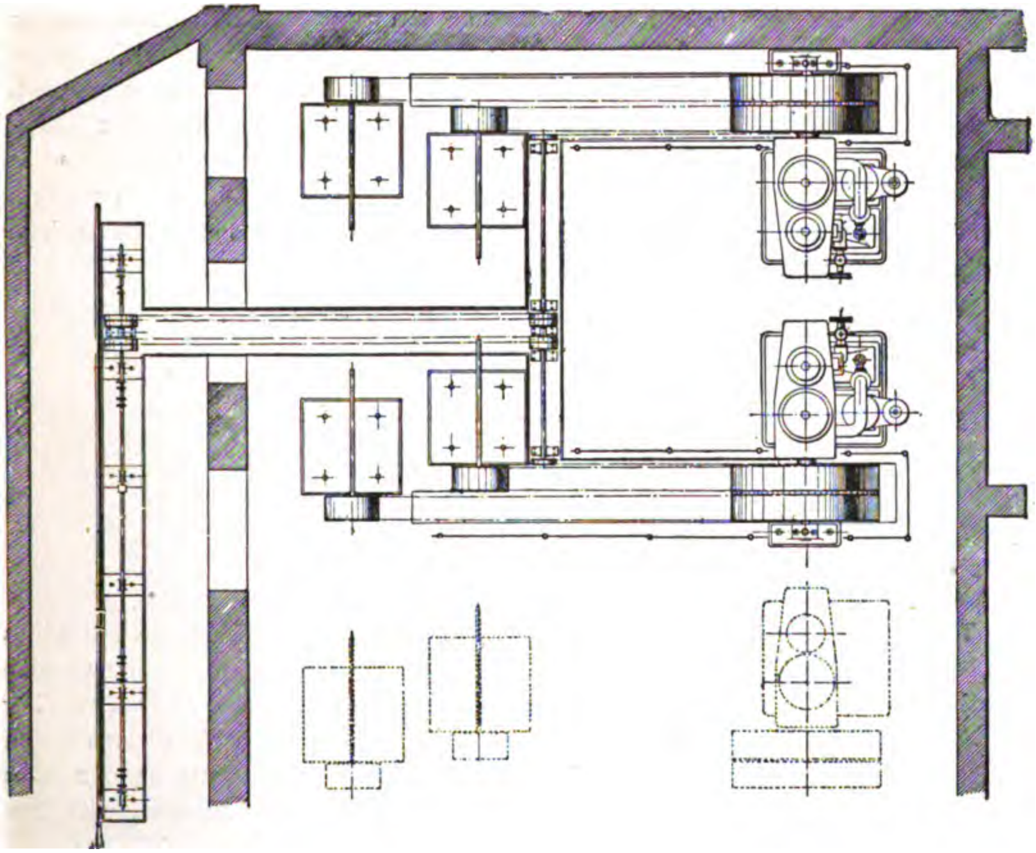


FIG. 52.—ENGINE ROOM, BREMEN.

The arc and incandescent lamps are all worked from the same machines, the former being put two in series. There are four generating dynamos of 67,000 watts capacity each, driven by two 180 H.P. steam engines, to which two other dynamos with a similar engine will be added when required. The installation was commenced at the beginning of 1888 and started working on September 25; it has since been extended by the erection of accumulators.

The steam engines are compound condensing, from the firm of Gutehoff-

nungshütte, Oberhausen; the cylinders have a diameter of 15·2 in., and 26·4 in., with stroke of 20 in.; the brake horse-power is 180 at 150 revolutions per minute, with 90 lbs. pressure and a cut-off of 0·38 in the high-pressure cylinder; each machine has two fly-wheels of a diameter of 8 ft. 4 in.

The dynamos, which are driven by belts, as shown in Fig. 52, are of Schuckert's flat-ring type, similar to those at Hamburg, with compound winding.

The switch-board is placed in an adjoining room and, as at Hamburg, regulators are used for keeping the potential of the mains constant; the switch-board stands away from the wall, so that the regulating resistances and other apparatus may be placed behind it. The automatic regulators are worked by a small shaft, which can be driven by either engine. This is shown on the left of Fig. 52.

Although some of the buildings lighted are at a considerable distance from the generating stations, the two-wire system was considered the most suitable. Out of twelve circuits, two supply arc lamps at a distance; the other ten circuits supply both arc and glow lamps. The length of the different mains, including the return lead, is from 100 to 2000 yards, the fall of potential at full load (with 2000 glow lamps and 80 arc lamps) being 15 volts. The mains are partly lead-covered, laid in iron conduits as in Hamburg, and partly consist of armoured cables; these supply mains have distributing boxes where the house connections are made.

LUBECK.

The first proposal to erect an electric light station was made by the authorities of Lübeck in July, 1886. The present installation was designed for supplying 3000 glow lamps of 10 candle-power, and 100 arc lamps (4 ampere) or their equivalent. For this were provided three boilers with 750 square feet heating surface, three steam engines, one of 50 and two of 115 H.P., six dynamos of 42,000 watts, and six miles of cables for distributing the current. The installation was commenced with two dynamos in the spring of 1887, and started working in November of the same year, the fifth dynamo being put up in November, 1888. The boilers are of the "Heine" system, able to evaporate 4 lbs. of steam at 100 lbs. pressure per square foot per hour; they are placed in a room adjoining the engine-room. A chimney 130 feet high is provided for the furnaces.

The condensing steam engines were furnished by the Nüremberg Maschinenbau Aktiengesellschaft; the larger ones, intended for the main supply, are compound, with cylinders of 15·2 in. (380 mm.), and 22·8 in. (570 mm.), the stroke being 32 in. (800 mm.). These machines, at 85 revolutions per minute, and an initial steam pressure of 100 lbs., give 115 H.P., which could if needed be increased to 200 H.P. The small

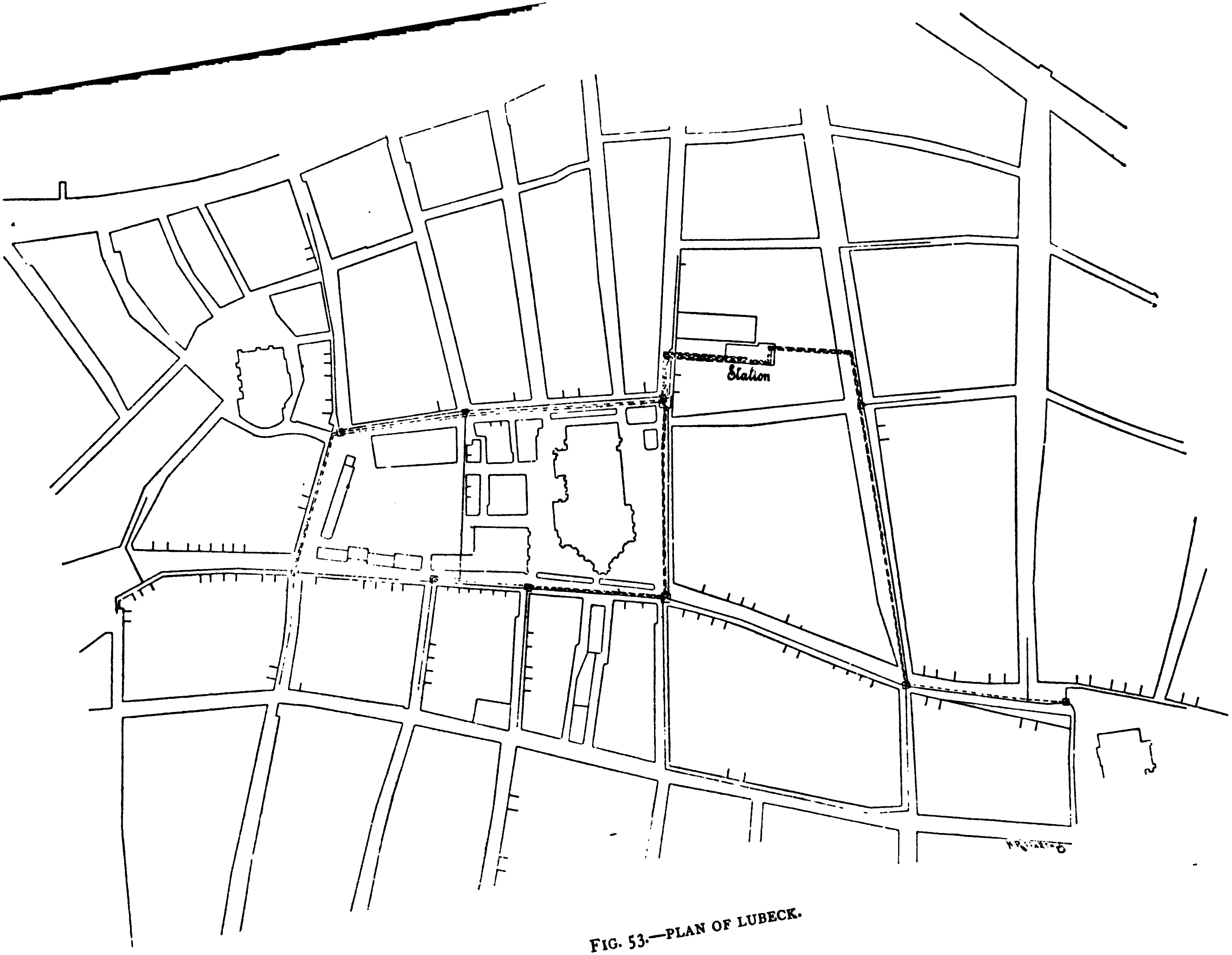


FIG. 53.—PLAN OF LUBECK.

L

engine has a stroke of 26 in. (650 mm.), and at 85 revolutions per minute and 100 lbs. steam pressure develops 50 H.P. The dynamos employed are of Schuckert's flat-ring type with compound winding. The switch-board is placed on one side of the machine-room close to the dynamos, the automatic apparatus being worked in exactly the same way as at the Hamburg Harbour Station.

On account of the favourable position of the central station and the compactness of the district supplied (shown in Fig. 53), a two-wire system was first employed, in nine main circuits, with an electromotive force of 103 volts, arc lamps being put two in series; in consequence of the increased demand for current, this was afterwards changed to a three-wire system. The maximum loss of potential is 15 volts in the mains and 1·5 volts in the distributing leads. The total length of the mains, all of which are double lead-covered, laid in iron conduits, amounts to six miles, the district supplied extending to a distance of 600 yards from the central station.

HAMBURG ELECTRIC LIGHT STATION.

This installation, designed for 12,000 glow lamps of 16 candle-power, is provided with one dynamo of 67,000 watts output, and five dynamos of 134,000 watts. Two compound vertical condensing engines are used, one driving the small dynamo and one of the larger, the other driving the remaining four dynamos.

The installation was started with this amount of machinery in December, 1888, being so arranged that the plant could be increased to double this extent if required. Fig. 54 shows a diagram of the arrangement.

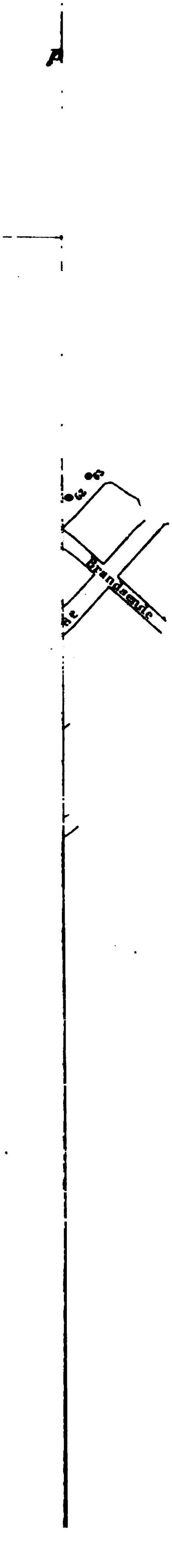
The Schuckert compound dynamos run at 300 revolutions per minute. The switch-board and apparatus are arranged on a gallery at the side of the machine-room, being practically identical with the appliances previously described (Fig. 49); the automatic regulators are, however, worked by two electromotors.

The current is distributed by eighteen main circuits on the two-wire system, two of these circuits being for the theatre. At the full load of 12,000 lamps, the loss in the feeders is 15 volts, and 1·5 volts in the distributing leads. There are nineteen miles of cable, double lead-covered and laid in iron conduits, extending to a distance of 1000 yards from the station. The feeders end at the distributing boxes, where connections are made to two rings. The mains are also provided with testing wires going to the station for indicating their potential. The iron conduits are made large enough to take more cables when they are required, in which case the network of conductors could also have an increased capacity by using it on the three-wire system.

Plate IX. shows a plan of the town of Hamburg, with its distribution of arc lamps, the number of incandescent lamps in the different installations being also indicated by the small figures.

The number of glow lamps installed was 8970 at the end of March, 1891, besides 361 arc lamps, of which only 5 per cent. were for private lighting. The current required

Plate IX.



for the whole would be 5559 amperes, whilst the greatest current supplied was, on December 20th, 3500 amperes, being equal to 63 per cent. of the lamps installed. It

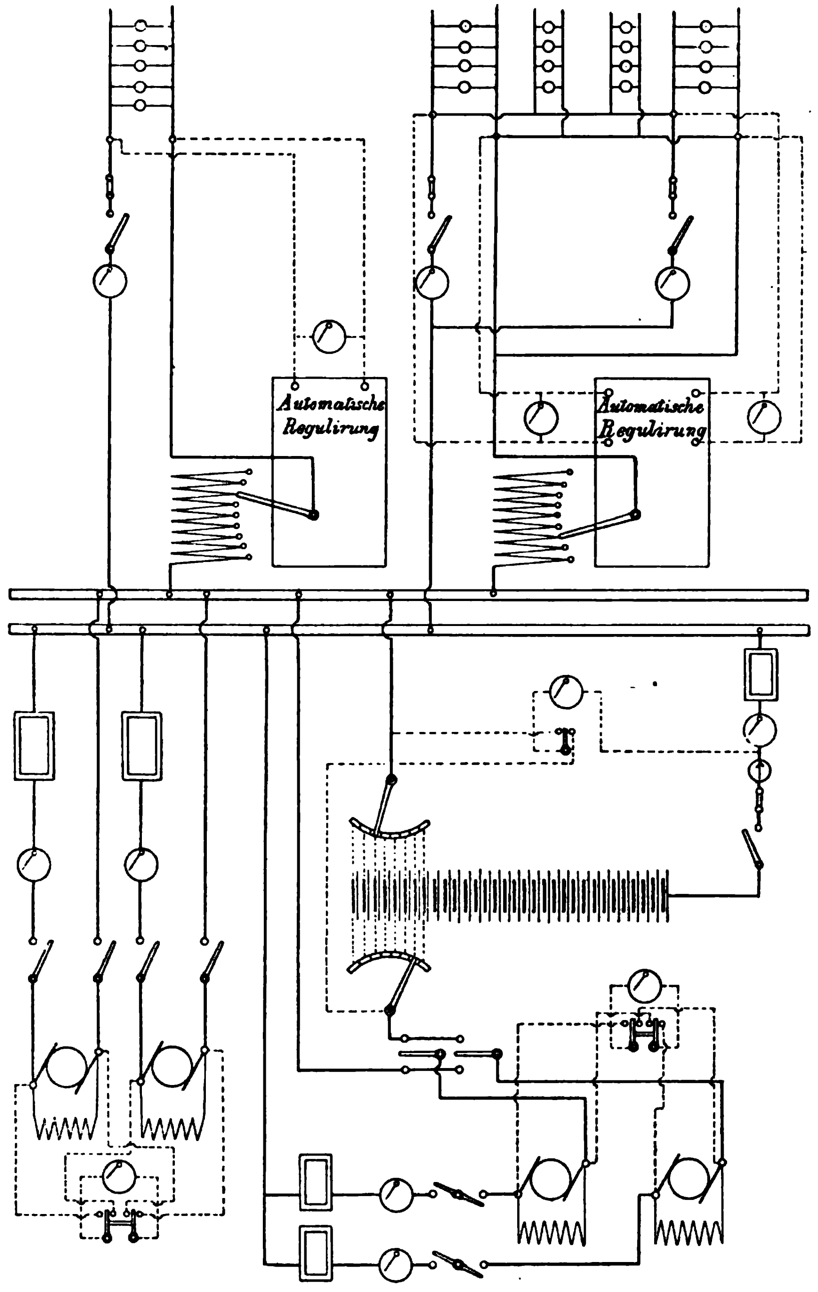


FIG. 54.—ARRANGEMENT OF STATION, HAMBURG.*

is intended to increase the capacity of the station for a further number of 3000 lamps by the erection of secondary batteries.

* Automatische Regulirung—Automatic Regulator. *See* Fig. 49.

BARMEN ELECTRIC LIGHTING.

The following account of electric lighting at Barmen shows a further development in the distribution of electricity, namely, by the use of secondary batteries. The stations erected in Heubruch, Victor, and Karoline Streets cover a ground space of about 25,000 square feet, and have suitably arranged boiler-house, engine-room, battery-room and offices, shown in Figs. 55, 56, 57 and 58.

The installation provides for a supply of 5000 lamps of 16 candle-power, or their equivalent, chiefly distributed in the centre of the town of Barmen. When complete, there will be six boilers, each with 1000 square feet heating surface, steam pressure 120 lbs; five compound non-condensing steam engines, to give 150 H.P. at 110

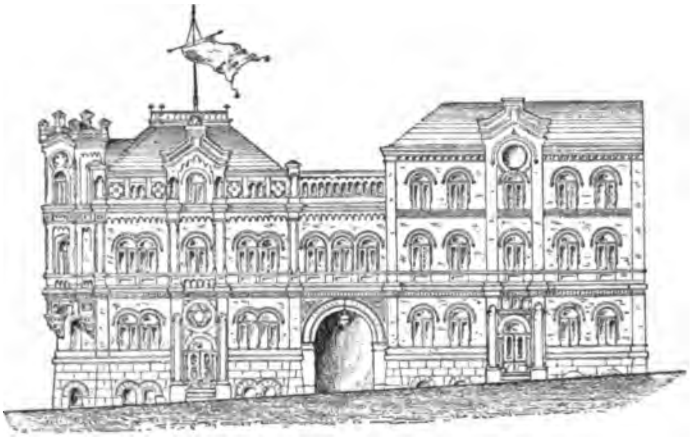


FIG. 55.—VICTORSTRASSE STATION, BARMEN.

revolutions per minute and 112 lbs. initial pressure; four double sets of Tudor batteries, 68 cells each, with a discharging current of 220 amperes; one steam engine, with its corresponding boiler and dynamos, being kept in reserve.

The buildings and mains were arranged for the full number of 5000 lamps; but, at present, machinery has been put down sufficient for about 4000 lamps only, the plant installed being three boilers, two steam engines of 100 H.P. and one of 150 H.P., with a corresponding pair of dynamos and two double sets of batteries.

The current is distributed on the three-wire system; one engine drives by belting two dynamos supplying the mains, the accumulators being in parallel with them. The dynamos are Schuckert's multipolar shunt-wound, giving 31,250 watts at 500 revolutions per minute.

By using accumulators, the working load of the generating machines is kept constant; the batteries are provided with multiple switches in the charging and discharging circuits, the difference between the output of current from the dynamos and the demand for the lamps being utilized in charging the cells. With two pairs of

batteries, from 2900 to 3600 lamps can be maintained simultaneously, ı set of machines as a reserve.

ıe present demand, a daily run of five or six hours is required ; at other times the batteries give practically a constant electromotive force on the mains, so that no supervision is necessary.

The current is distributed by means of 12 feeding mains, the voltage of which is kept constant by automatic regulators, which are worked by a shaft driven by two electromotors. The distributing mains form a network stretching over a district about a mile long and 650 yards wide ; this network has been estimated for 5000 lamps requiring 55 watts each, allowing a loss of energy of 10 per cent. from the dynamos to the lamps. The cables are laid on the three-wire system ; the total electromotive force is 220 volts, or 110 volts to each circuit. Forty-one cast-iron boxes are placed at various points, which can be got at by lifting off the iron covers ; the connections for the distributing mains, to which the house mains are soldered directly, are made at these

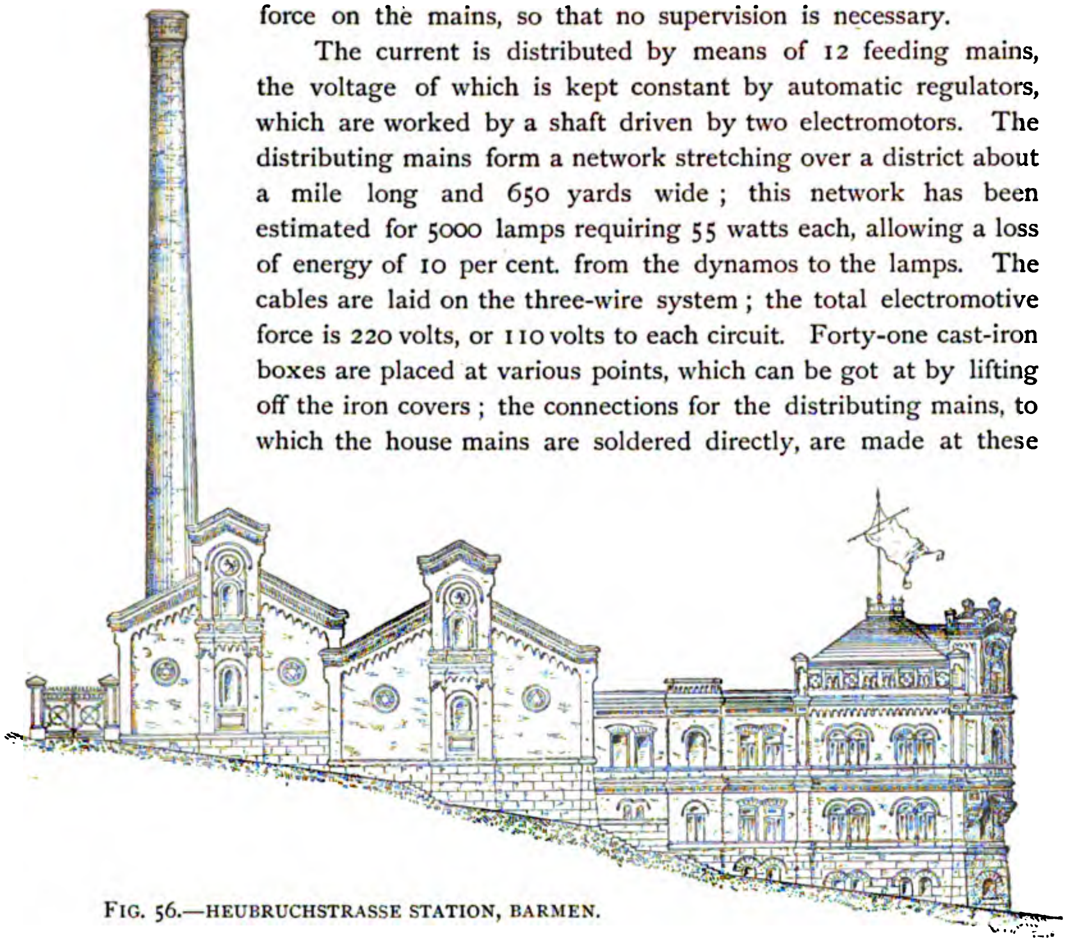


FIG. 56.—HEUBRUCHSTRASSE STATION, BARMEN.

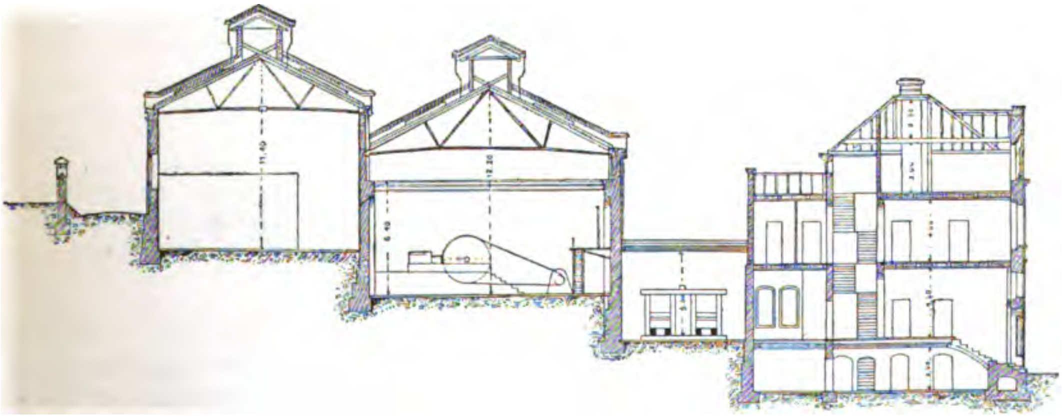


FIG. 57.—SECTION OF BARMEN STATION.

boxes. Each circuit is provided with lead fuses, so that a short circuit only affects the particular circuit in which it occurs. Within the houses the mains are supplied with fuses, and also switches for connecting the circuits to either branch of the three-wire system.

The double lead covering of the cables prevents the penetration of damp, and they are protected from mechanical injury by being doubly iron armoured. They are laid in sand at an average depth of a yard below the surface of the ground, and are then covered with four inches of earth, with a layer of bricks on top. In positions where it is impossible to put them a yard deep, the cables are protected from injury by placing over them stone slabs or wrought-iron plates, or else they are put in cast-iron pipes. The feeders have a total length of about 14 miles, the distributing mains about 17 miles, making a total of 31 miles, exclusive of the connections to the houses supplied.

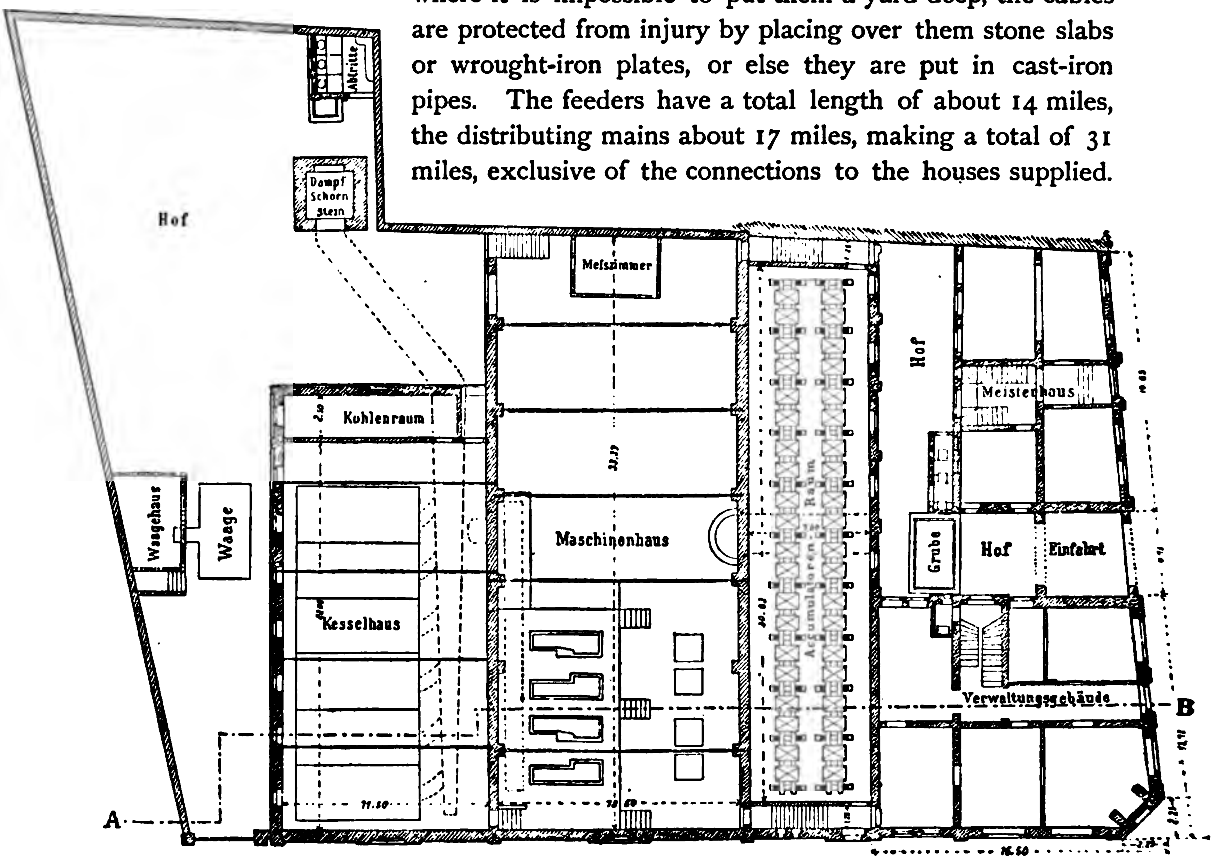


FIG. 58.—GROUND PLAN OF BARMEN STATION.

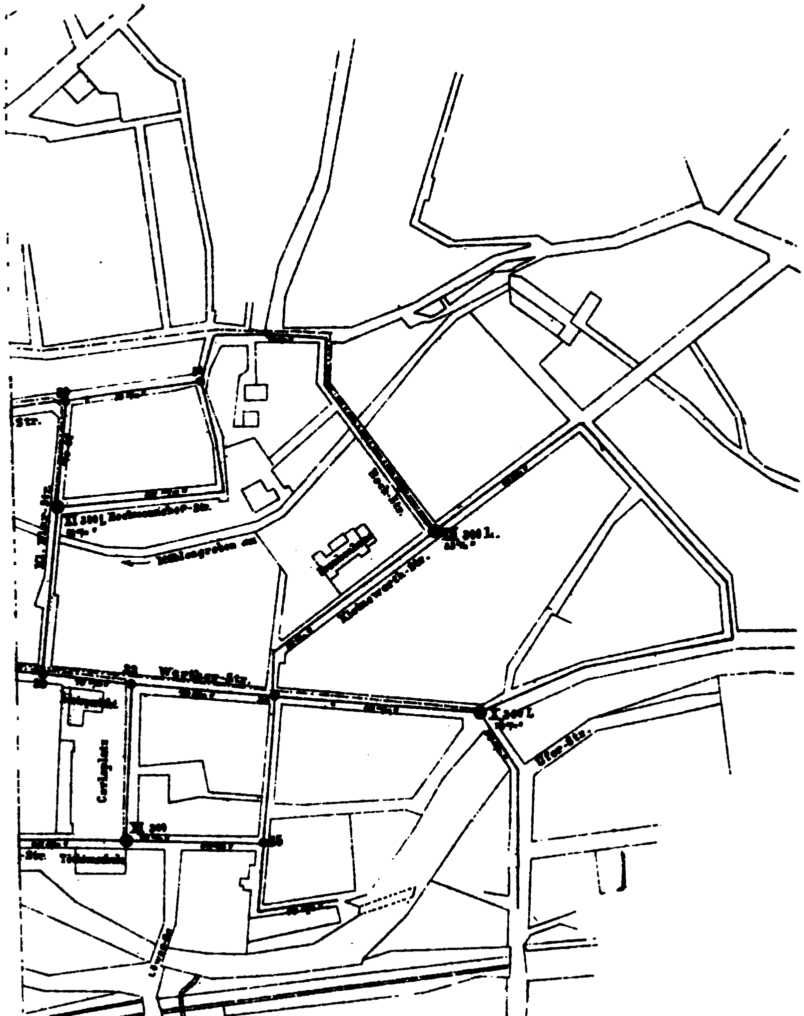
EXPLANATION OF FIG. 58.

Kesselhaus	Boiler House	Maschinenhaus	Engine Room
Kohlenraum	Coal Store	Schornstein	Chimney
Hof	Yard	Messzimmer	Testing Room
Einfahrt	Entrance	Waagehaus	Cart House

Dimensions are in metres.

To show which are positives and which negatives, for facilitating repairs and the laying of further cables, all *positives* have two iron wires and all *negatives* one wire between the lead and iron coverings; also, the former are always laid in position to the right and the latter to the left.

Plate X.



The current used by consumers is measured by an Aron meter, the cost being ½d. (4 pf.) per lamp hour of 16 candle-power, requiring 55 watts.

The installation, which has cost about £37,500 and started working in December, 1888, is under the management of the town authorities of Barmen, who also undertake the sale of carbons and glow lamps. There are about 110 arc lamps (of 4 to 10 amperes) and 3000 glow lamps of 10 to 25 candle-power.

Plate X. shows a plan of the town of Barmen, with its network of distributing mains.

It is proposed, in order to supply the district surrounding Barmen, to erect five battery stations, the main central station furnishing the current for charging during the day-time. Secondary batteries answer the same purpose for electric lighting as reservoirs for gas and water-works, but it is necessary that the adoption of batteries should not involve the use of complicated apparatus, nor result in great losses through storage. By means of multiple switches the electromotive force supplied to the mains can be kept constant, and also the pressure in the charging circuit, so that the generating machines work at a constant load without the employment of wasteful resistances.

HANOVER CENTRAL STATION.

The building for this installation has, in view of the expected increase in the demand for current, been arranged for plant sufficient for 30,000 lamps of 16 candle-power, the space taken up being 115 feet by 76 feet. The present plant is capable of supplying about 12,000 lamps, and plans have already been made for shortly increasing the output up to 30,000. Plates XI. and XII. are taken from the working drawings, and show an elevation and ground plan of the building, which is divided into three parts respectively for the boilers, engines, and battery. Plates XIII. and XIV. show the arrangement of the switch-board; on the latter will be found an explanation of the connections.

The boilers, supplied by Steinmüller, have the advantages of great simplicity and freedom from danger; they have great capacity for their size, with a heating surface of 1950 square feet, by means of 120 wrought iron tubes of 3·8 inches (95 mm.) diameter. Each boiler will evaporate 600 gallons of water per hour at 175 lbs. pressure, requiring about 660 lbs. of coal. The fuel is conveyed to the furnaces by coal waggons on rails. The chimney has a height of 160 feet and a diameter of 67 inches, the firing being effected without giving any trouble to the surrounding district on account of smoke. The steam generated passes through pipes 11·2 inches (280 mm.) in diameter to the engines, which were built by Schichau and are of similar type to those used in the German navy for torpedo boats.

The two engines at present running have a normal output of 350 H.P., but can be worked up to 450 H.P.; the diameters of the cylinders are 16·8 ins. (420 mm.), 27·6 ins. (690 mm.), and 42 ins. (1050 mm.), with a stroke of 20 ins. The most economical working of these machines has been with a consumption of 1·55 lbs. (0·7 kilos) per

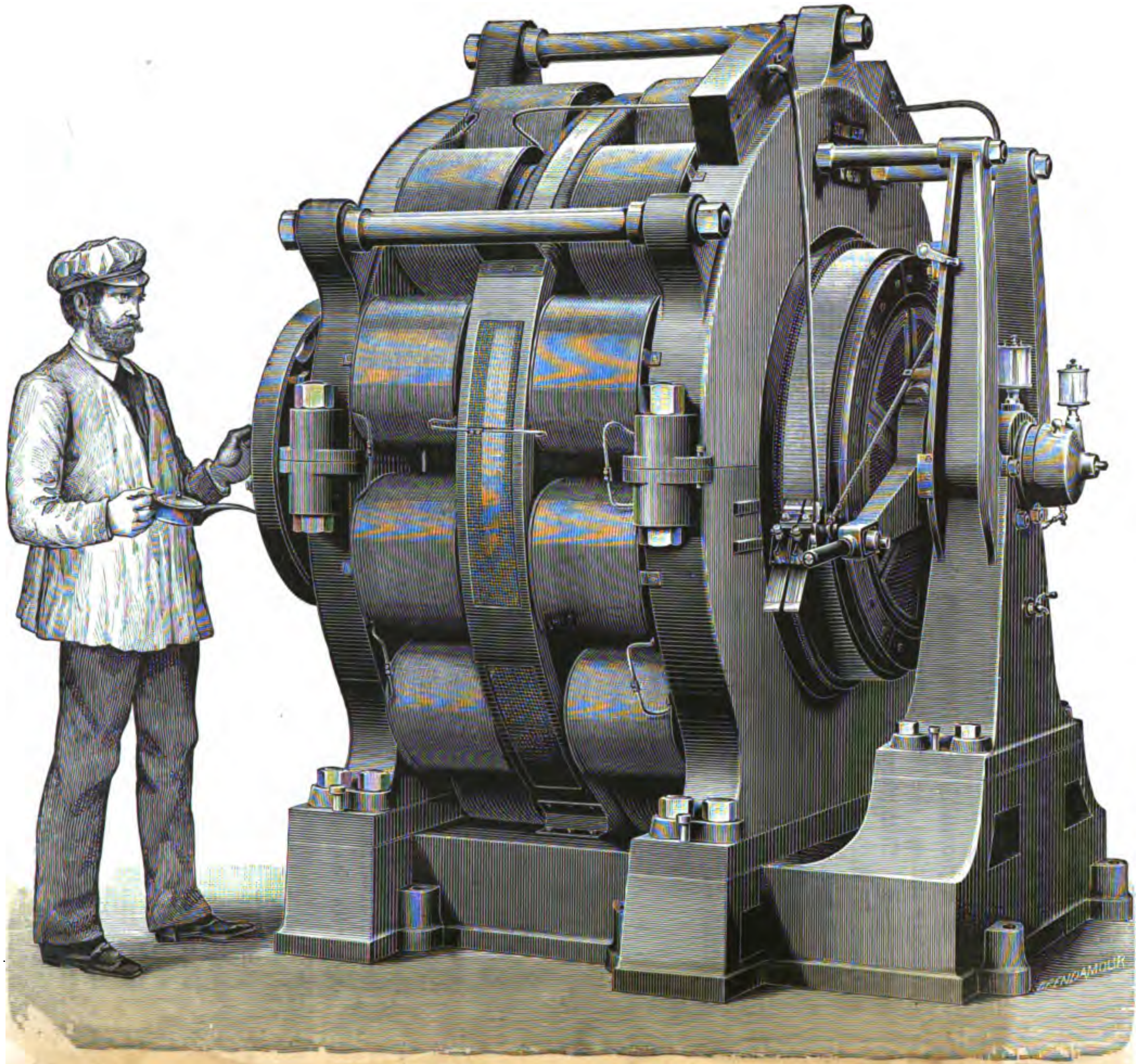
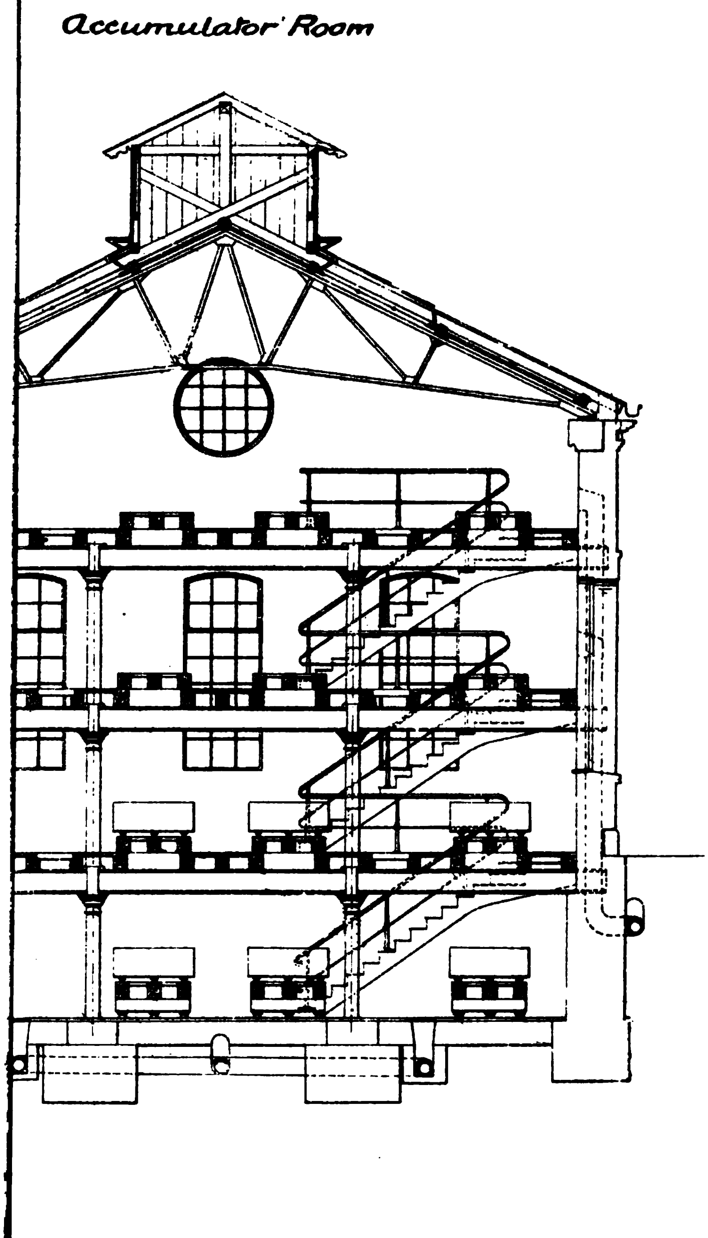


FIG. 59.—SCHUCKERT DYNAMO.

Plate XI.



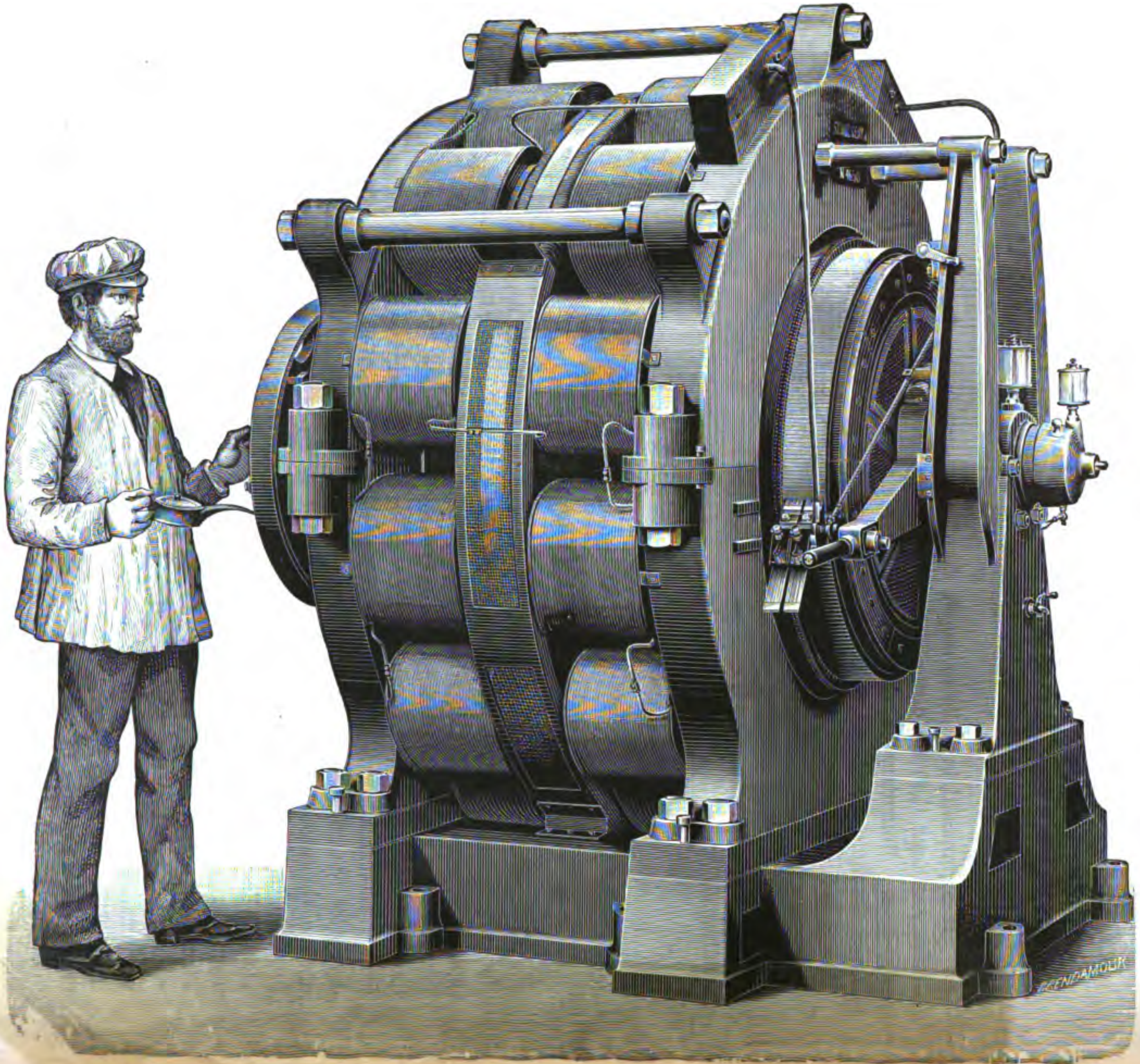
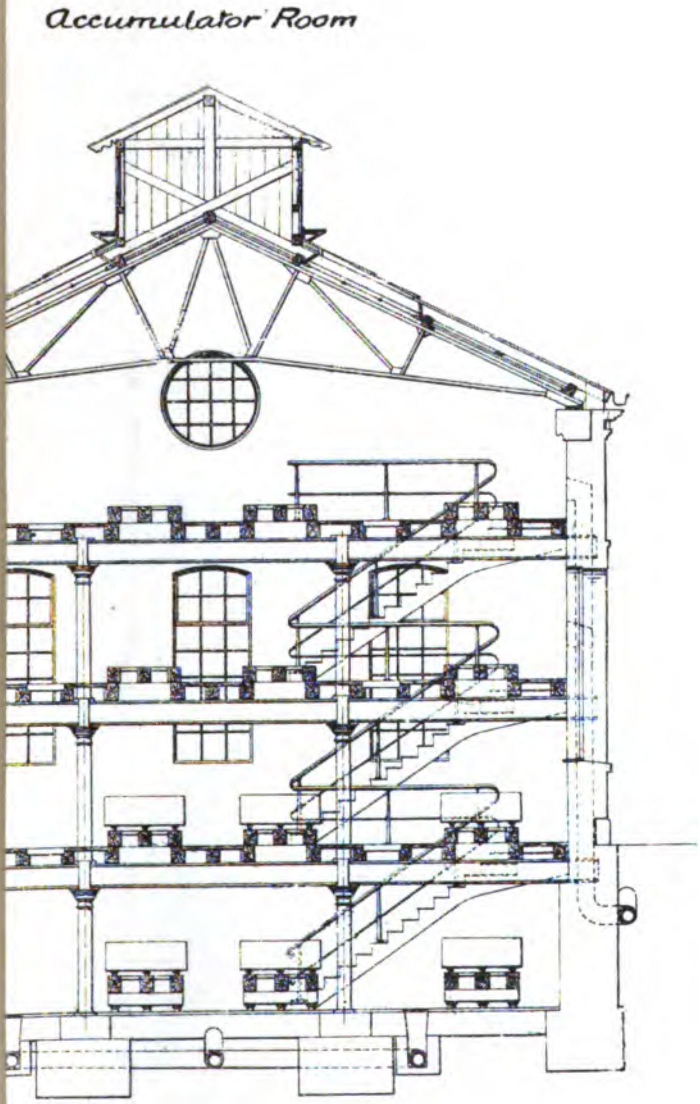
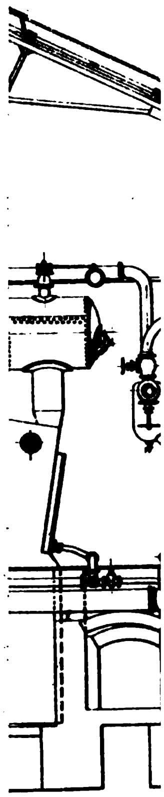


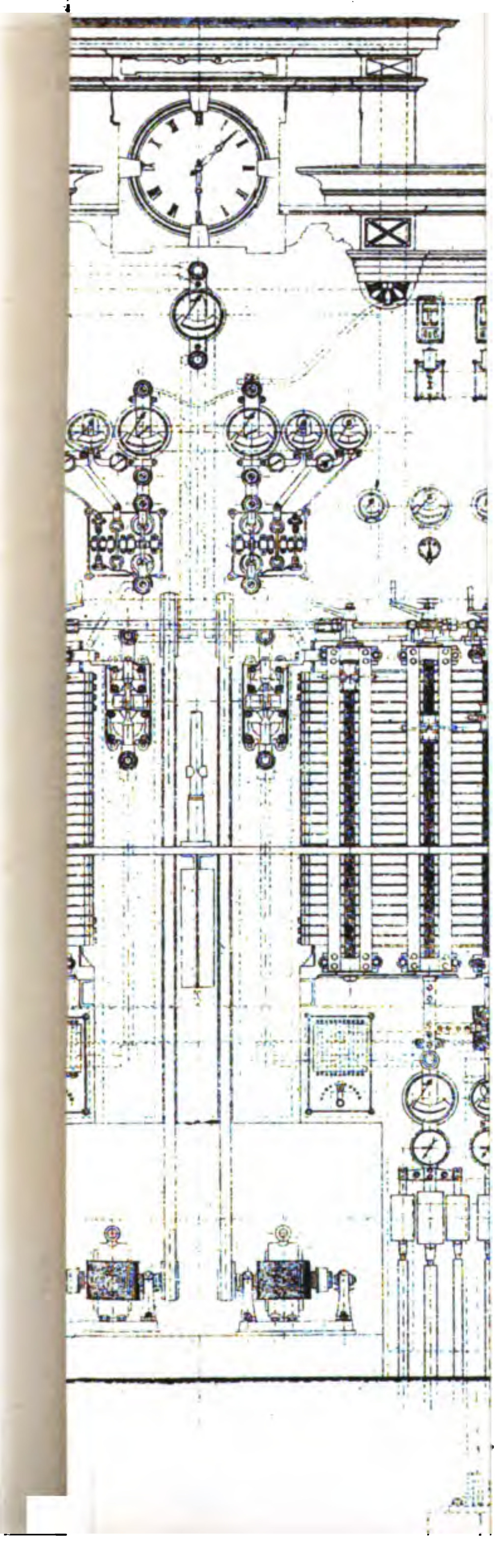
FIG. 59.—SCHUCKERT DYNAMO.

Plate XI.

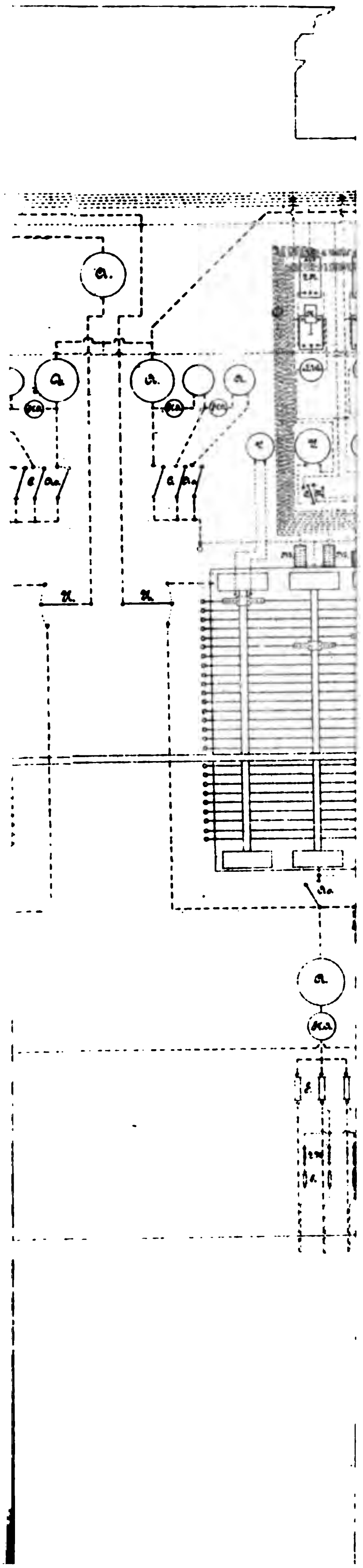




p.80.



30.



effective H.P. The steady running obtained with the three cylinders obviates the necessity for a fly-wheel, the dynamos being also coupled directly to the engines, running at a speed of 115 to 120 revolutions per minute.

The Schuckert flat-ring dynamos, shown in Fig. 59, have armatures about 10 feet in diameter, with 840 sections, and commutators of 6·6 feet diameter. The necessary apparatus for regulating and measuring the current is arranged on the wall between the engine and battery rooms. The accumulators are placed on four floors, each battery consisting of 136 cells of 1320 ampere-hour capacity, and a discharge current of 396 amperes; suitable means are provided for ventilating.

The cables are lead-covered, the distributing mains being iron-armoured and the feeders laid in iron conduits; the total length laid is about 50 miles, the greatest distance from the station being about 1300 yards.

This installation at Hanover started working on the 3rd of March, 1891, and within a few days over 8000 lamps were being supplied.

DÜSSELDORF CENTRAL STATION.

When the district extends to a distance, or the station is a long way from the point of consumption, indirect working is more economical, such as a system with sub-stations provided with secondary batteries, as illustrated in Fig. 60.

The generating station is situated a mile and a half from the centre of the town of Düsseldorf, and supplies current for charging secondary batteries in three sub-stations. When complete, the plant will be sufficient to maintain 20,000 glow lamps.

The building for the machinery covers a surface of 11,000 square feet, space being provided for three steam engines of 300 H.P. normal load and 400 H.P. maximum. The boilers, of which there are three at present (the third being kept in reserve), came from the Hohenzollern Aktiengesellschaft, and have a heating surface of 1650 square feet, each having 103 tubes of 3·8 ins. diameter. Over the boilers are two steam collectors 3 feet in diameter and 19 feet long. The evaporation of steam is guaranteed to be at the rate of 2·86 lbs. per square foot of heating surface at 135 lbs. pressure. The horizontal tandem steam engines, purchased from the Sächsischen Maschinenfabrik, work with a steam pressure of about 120 lbs. and at a speed of 90 revolutions per minute; the diameters of the high and low pressure cylinders are 18 ins. and 30 ins., the stroke being 40 ins. The engines have Hoffner's patent system of valve regulation, and work with surface condensers.

The electrical generators used are Schuckert's flat-ring dynamos, the first employed of a new type. The cast-iron cover of this dynamo, with which are cast the fourteen field magnet cores, encloses the whole machine. The armature has a diameter of 10 feet and the commutator 6·6 feet, the latter having over 800 sections. From these dynamos a current of 1000 amperes at 350 volts can be obtained.

Of the three sub-stations, which are connected by telephone with the main station, the largest has two batteries of 140 Tudor cells, each with a discharge current of 483 amperes, the other two having the same number of smaller cells with a discharge current of 248 amperes.

This installation maintains the 2700 glow lamps in the theatre, and also those at the railway station, a separate sub-station in Karlstrasse being used for the latter. The current was turned on September 1st, 1891, with about 6000 lamps of 16-candle power, most of which burn the greater part of the evening.

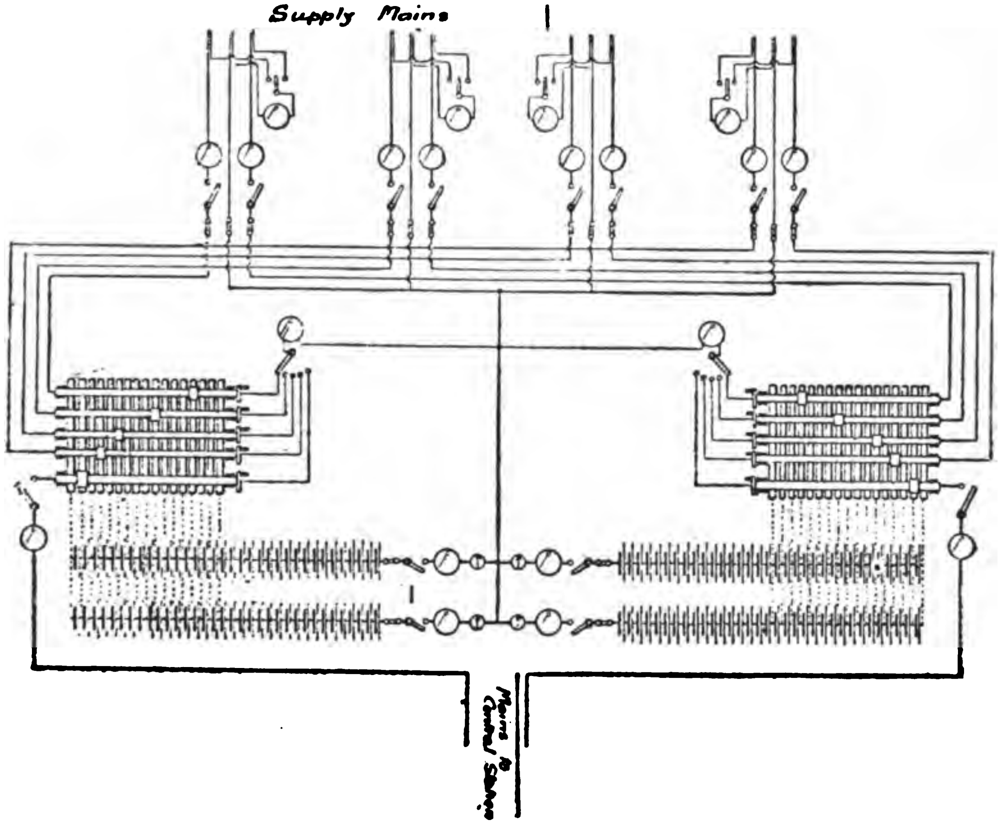


FIG. 60.—SECONDARY BATTERIES, SUB-STATION SYSTEM.

The consumer has to bear the costs of connecting up unless he has agreed to subscribe for three years, in which case the Municipality will bear the cost.

The charge for current is 11*d.* (90 pfennigs) per Board of Trade Unit, but if the consumer pays more than £10 annually, discount is granted, as shown in the table below.

				£		£
4	per cent.	if	between	10	and	50
8	"	"	"	50	"	100
12	"	"	"	100	"	150
16	"	"	"	150	"	200
20	"	"	"	200	"	250
24	"	"	above	250		

The meter rent per month is for—

	s.	*d.*
15-light meter	1	0
30 " "	1	6
60 " "	2	3
100 " "	3	0
Each additional 100 lights .	1	0

THE COMBINATION OF ALTERNATING AND DIRECT CURRENTS.

THE MULTIPHASE SYSTEM.

If the distance to which power has to be transmitted is excessive, it is advantageous to employ alternating currents with transformers arranged as follows. At the generating station are alternate-current machines of low voltage, the current from which is raised by a transformer to supply the mains; at the sub-stations the current is lowered again in potential, and commuted into a continuous current to charge accumulators. This plan combines the advantages of a high-potential

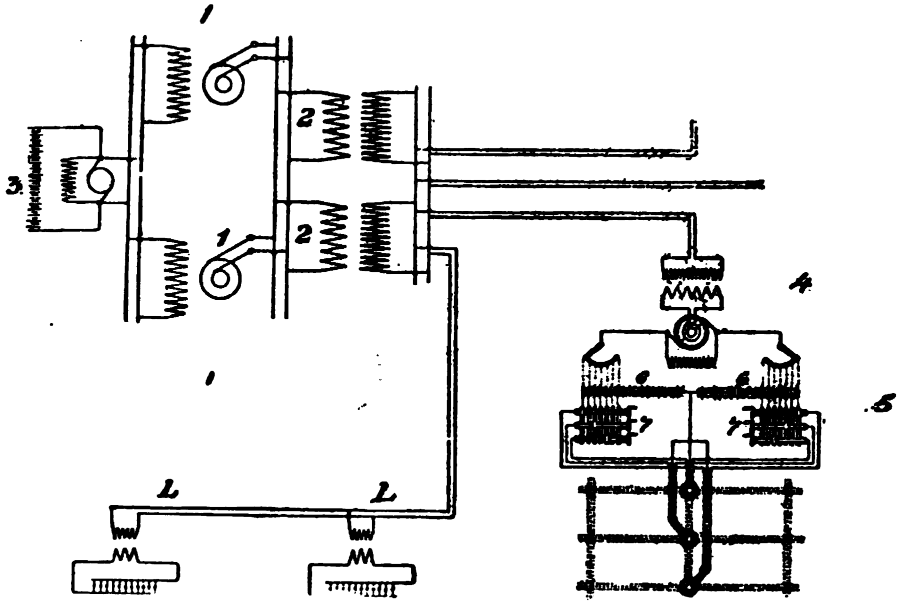


FIG. 61.—ALTERNATE-CURRENT SYSTEM WITH SUB-STATIONS SUPPLYING DIRECT CURRENT.

system to give economy in the mains and also of a low-potential distributing system with accumulators. The arrangement will be understood by referring to Fig. 61, which shows diagramatically how the connections are made.

DESCRIPTION.

1. 1. Alternating-current dynamos.
2. 2. Primary high-tension transformers.
3. Exciting continuous-current dynamo.
4. Secondary transformer, producing continuous currents by dynamo-motor.
5. Continuous-current sub-station.
6. 6. Secondary batteries.
7. 7. Regulating switches.
L. L. Line carrying alternating current to consumers at a distance.

In Fig. 61 there is a necessity for two complete sets of plant, namely, alternating and continuous; Messrs. Schuckert have, however, introduced what is termed

the multiphase system, which enables all the operations to be carried out by means of dynamos of one type.

The term "multiphase" is at first confusing, but perhaps it is the best that can be used to describe the principle on which the arrangement lately exhibited at the Frankfort Exhibition by Messrs. Schuckert is based. To Galileo Ferraris, of Turin, the honours of discovery are due, but the putting in practice has been facilitated by the experiments of Tesla and Bradley. From the latter, especially, comes the so-called coupling of alternating currents, that is, their collection from fixed places of a continuously-wound armature, like the Gramme ring or the Hefner drum. The current from either of these would be of course an alternating one, and in practice is

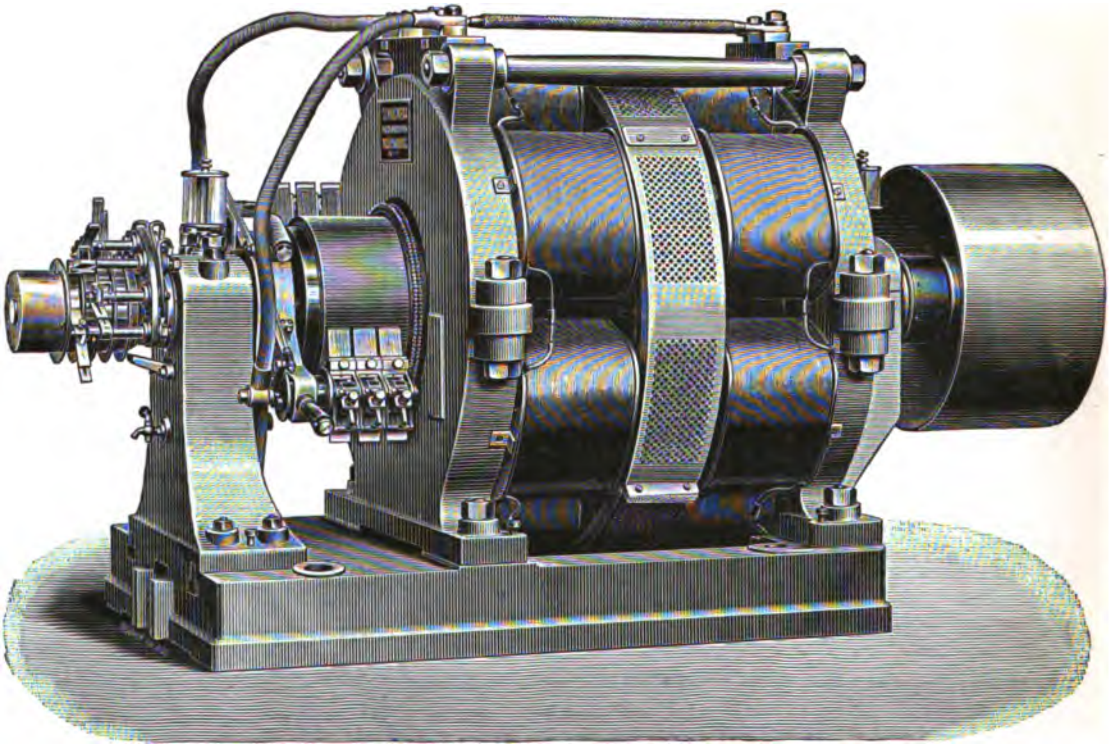


FIG. 62.—NEW FORM OF ALTERNATING DYNAMO, SCHUCKERT & CO.

changed into a continuous current by the well known Paccinotti commutator. In the Schuckert arrangement there are four points from which the current is led to the collectors, which are joined into two circuits. In the multiphase system the two circuits are branched from four points, disposed symmetrically on a continuously-wound ring, so that two alternate currents with a 90° difference of phase are produced; that is, when one current is at its maximum strength the other is at zero. The dynamo Fig. 62 has also in addition to these collecting rings an ordinary continuous-current commutator, and differs from the ordinary type of machine in that current can be taken from it for various purposes and it can be used in a variety of ways: thus—

1.—An ordinary continuous-current machine.

2.—A self-exciting alternating-current dynamo for generating one or two alternating currents.

3.—As a continuous-current motor.

4.—As an alternating-current motor.

5.—As a transformer to convert continuous into alternating currents.

6.—For the converse to No. 5.

Finally, these different applications can be combined.

At the exhibition it was in constant use as a dynamo-motor, first to generate alternating current which was led to motors and utilized for the purpose of driving the machinery of exhibitors in an adjacent building, and at night a number of lamps were maintained from the continuous current produced by the same machine. A difficulty, which at first appears very great, namely, the starting of the machine as a motor, is explained by Messrs. Schuckert as follows: "On starting as a multiphase motor the armature takes up the alternating currents, which were led to the exhibition from a dynamo at the Palm Garden about two and a half miles away. As previously explained, one alternating current is always at its maximum while the other is at its minimum strength. The magnet bobbins are at first out of action, no current being sent through them, but a current is produced in them by the magnetism induced in their poles by the currents in the ring. So far, the ring does not rotate, but simply moves, and has the tendency to place itself in such a position that the poles in the ring caused by the magnetic lines of force spreading out from the magnets are opposite; but as the magnetic poles of the ring rotate, so the ring itself begins to turn round, and it is thus easy to see that, once having started, it is possible to increase the power of the motor by sending the current round the bobbins of the fixed magnets. If an alternating current was used to excite these magnets, then it would be necessary to make their cores laminated; it is therefore better and cheaper to excite with a continuous current, as then the cores can be made of cast-iron, and also less current is required for their excitation. It would not do to turn the self-generated continuous current round the bobbins until the motor is in synchronism with the generating dynamo—were they excited before this happens, the motor would not start, since the impulse which it receives through the attracting power of the magnets would not always act in the same sense. The attendant finds out when to turn on the exciting current by means of a voltmeter connected to the copper winding of the magnets. As long as the motor does not run in synchronism, the magnetic pole in the ring will obtain its magnetic circuit at times through the air and at times through the iron cores of the bobbins. This alters the number of lines of force passing through the iron cores, and consequently produces an alteration in the current passing through the bobbins. The voltmeter at first gives a considerable deflection, but as the motor synchronizes the readings become gradually less and less until they fall to zero. The same voltmeter will now show the electromotive force of the continuous current which can now be switched on, and the power of the motor is at once more than quadrupled." The 25 H.P. motors (which is the size previously described and shown by Fig. 63) are self-exciters, but it is found better to have a separate exciter for the large machines,

The alternating currents were generated by the dynamo in the Palm Garden at 100 volts, and were transformed upwards to 2000 volts by means of Schuckert's new form of ring transformer. It consists of a double flat ring, the first being notched to receive the windings, while the second is put on top of it and closes the magnetic circuit. Another similar transformer, fixed in the exhibition, brought down the current to the required voltage.

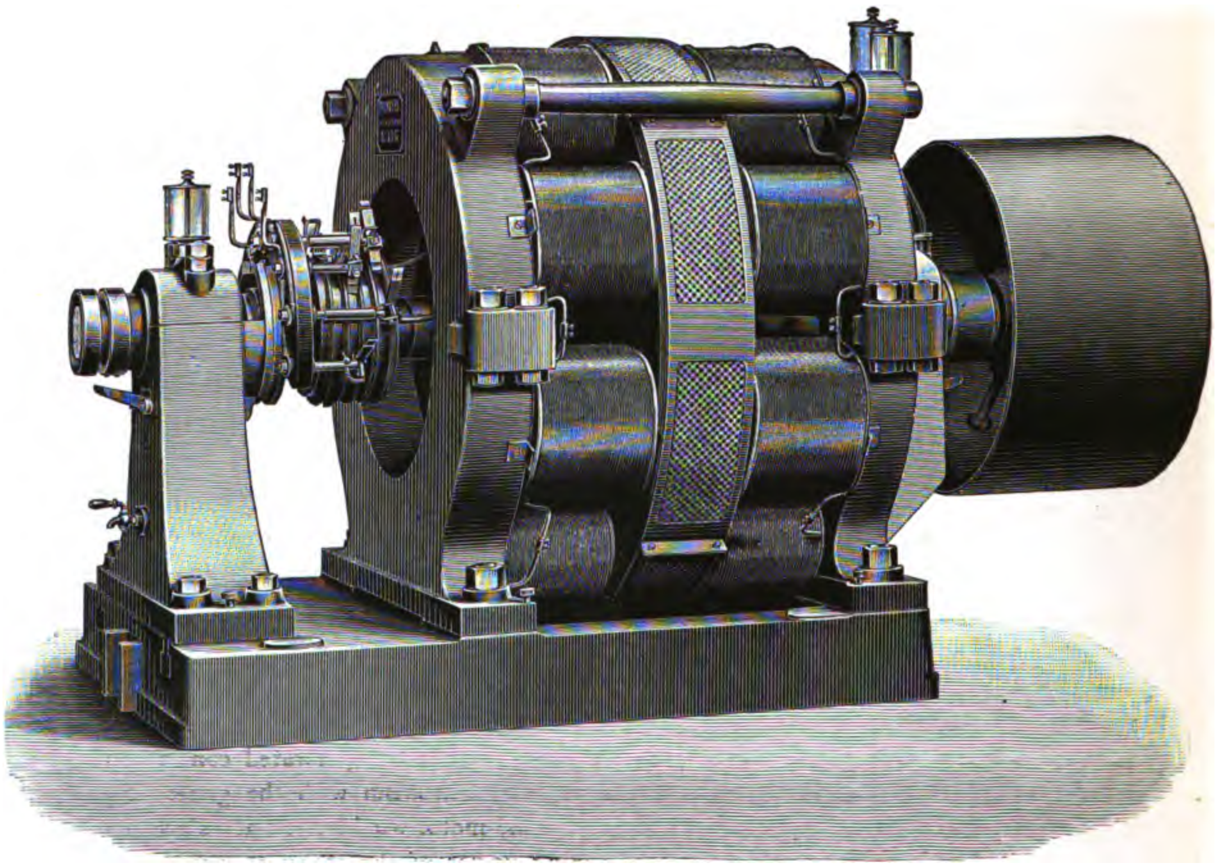


FIG. 63.—25 H.P. MULTIPHASE-CURRENT MOTOR, SCHUCKERT & CO.

The simplicity of the motor which has been described may bring it into use commercially; but on looking at the matter from the engineer's point of view, it appears that it would be better not to take both alternating and continuous currents from the same motor, although one cannot but admire the excellent manner in which Messrs. Schuckert have solved the problem.

ON THE APPLICATION OF ACCUMULATORS TO CENTRAL STATIONS.

THE ACCUMULATOR MANUFACTURING COMPANY, HAGEN, WESTPHALIA.

The use of accumulators or secondary batteries for a distribution of electricity may be said to resemble the use of gasometers in gasworks. They both permit, with a variable consumption, a steady, uniform, and economical generation of electric current or gas, and form a means of regulation.

Before the construction of accumulators was so fully developed, practical applications to large central stations could not be executed with advantage on account of the cost of such projects compared with that of systems employing alternating currents. The frequently expressed wish not to have generating stations, with their boilers and steam engines and numerous objections, such as smoke and noise, in the middle of a large town, but to locate the central station outside the town, is a praiseworthy arrangement, provided the cost in transmitting the electric power to the town from the station or stations outside is not excessive. For such purposes, before the application of accumulators had spread so widely, alternating currents were more suited. These alternate-current stations could be constructed for a suitably high tension in the outer station, afterwards to be transformed down at the consumers' premises; the current was thus brought to the town by small leads costing proportionally little.

The better and more substantial construction of accumulators has placed the system in a position to compete with alternating currents. By means of such application the difficulties of distance are overcome; also the use of continuous currents with accumulators is not only as reasonable with regard to capital required as an alternate-current system with transformers, but is also easier in management. Besides, the great superiority of the continuous over the alternating system must be brought into consideration; for instance, the pressure is more uniform, and motors can be operated without the slightest danger also current can be taken from the leads for various industrial purposes. All these advantages place the continuous current in an important position above the alternating system.

Accumulators can also be employed even if the electric current is generated in distant central stations, and transmitted to the town by means of alternating currents. In the accumulator station within the town, the high-tension alternating current can be transformed into a continuous one, as it can be so arranged that the high-tension continuous or alternating current drives a motor, which is mounted on the same spindle as a second machine which generates the continuous current.* This secondary generator is constructed in the same way as the motor, and runs parallel with the accumulators and network of distributing leads.

* *See* Dynamotors, p. 79, "Central Station Electric Lighting," Hedges, 1889.

If the central station is situated in or near the town, a direct continuous current is employed.

Fig. 64 shows a battery of Tudor cells, as supplied by the Hagen Company.

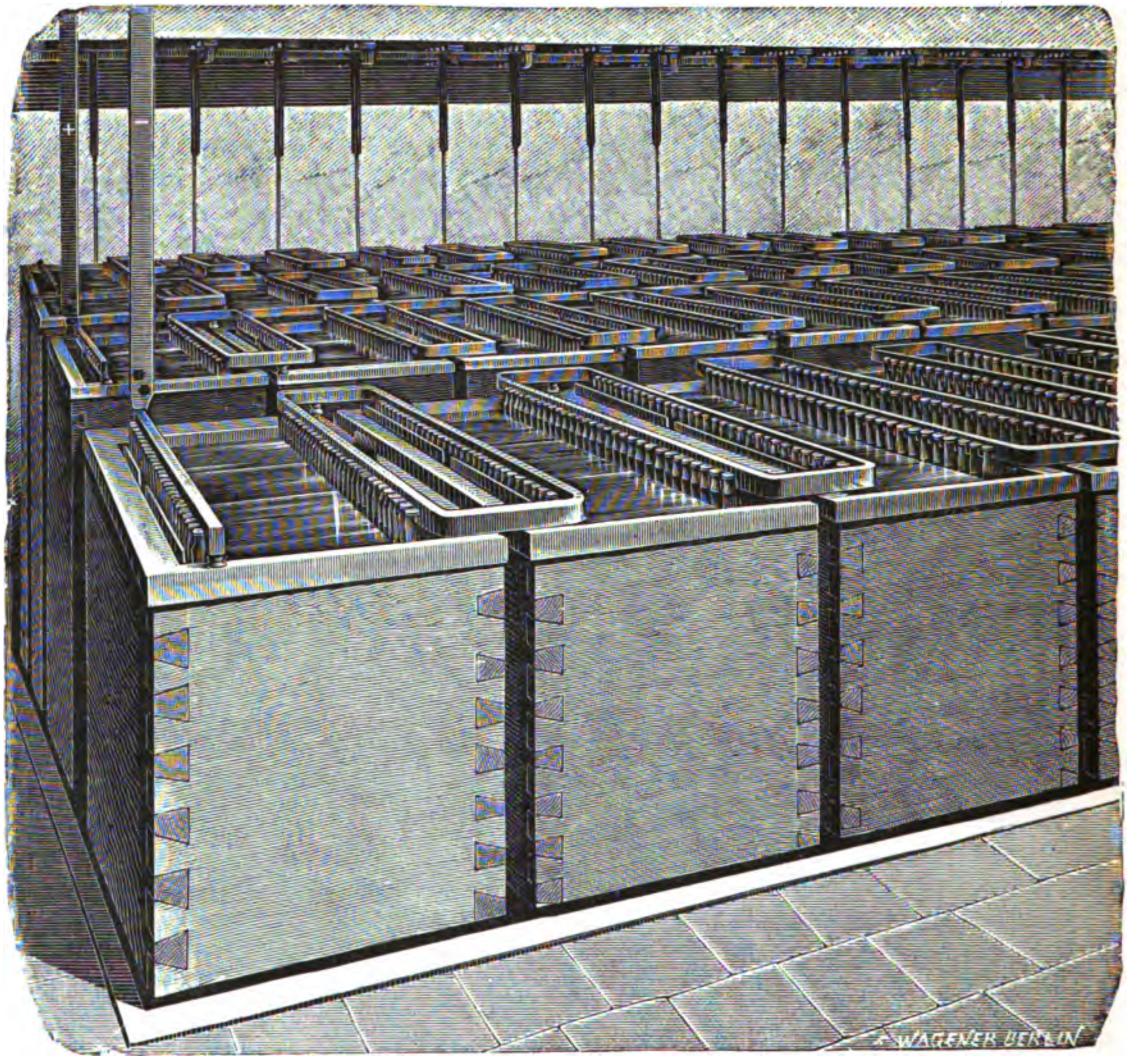


FIG. 64.—TUDOR SECONDARY BATTERY.

THE DESSAU CENTRAL STATION, 1886–1891.

CONTINUOUS-CURRENT DYNAMOS WITH ACCUMULATORS, MOTIVE POWER BY GAS ENGINES.

THE CONTINENTAL GAS COMPANY OF DESSAU.

After the German Continental Gas Company had, by a supplementary Statute of March 12, 1879, extended their sphere of action to the establishment of electric lighting, the first supply company was started September 13, 1886, in Dessau. The origin of the project was based on the idea that electricity could be economically produced by the combustion of gas by means of the gas engine.

After all the investigations and practical experience of the last ten years with combustible gases, and, indeed, especially with coal gas, the conclusion was arrived at that the generation of power directly by means of large gas engines had a very great future before it, and was more economical than using a number of smaller engines.

The electrical plant was supplied by the Allgemeine Elektricitäts-Gesellschaft and Siemens and Halske of Berlin, the gas engines by the Berlin Anhaltischen Maschinenbau-Aktien-Gesellschaft.

The engines consist of the following:—

Two 2-cylinder Otto gas engines, each 60 H.P. =	120 H.P.
One " " " "	30 "
One 1-cylinder " " "	8 "
	158 brake H.P.

The gas engines are coupled to four dynamos of suitable size. The 8 H.P. engine, generally worked at 10 brake H.P., is used for lighting during the day and for exciting the larger machines. For cooling the gas engines wrought iron chambers of a total surface of 1076 square feet are used, through which water is forced by the pressure of the town supply; or a small pump can be used, driven by a 1 H.P. electro-motor. The water consumption for cooling the engines averages during the year 5 to 5½ gallons per horse-power hour, whilst with newer and better apparatus it will certainly be worked much more economically. We would here remark that the not unimportant consumption of water for cooling the dynamo bearings is included in the above quantity.

The exhaust of the gas engines has, after many attempts, been rendered almost perfectly noiseless at Dessau, so that anyone standing outside the machine-room

can scarcely tell by the noise whether the large gas engines are working or not; only a white smoke, without smell, indicates the working of the engines.

At the opening of the station there were put up:—

Two	Edison	dynamos (35,000 watts)	=	70,000 watts.
One	„	„		23,000 „
„	„	„		5,000 „
				98,000 watts.

The dynamos work at a voltage of 110. After the installation of a larger set of accumulators in 1889, one of the two large dynamos was changed for one of higher electromotive force, 140 volts. The higher power of the new machine, giving 45,000 instead of 35,000 watts, about compensates for the loss in the accumulators. The total production of the dynamos is therefore 108,000 watts. The switch-board for the dynamos and cables is arranged according to the system of the Allgemeine Elektricitäts-Gesellschaft for two wires, whilst later on a three-wire system will be introduced. Over two miles of concentric iron-sheathed lead cables of Siemens and Halske are laid down.

After a small secondary battery for 100 lamps had been put up in 1887, in spite of its low efficiency of only 50 per cent. and its rapid deterioration, the advantages of accumulators were so apparent that in the summer of 1889 the small battery was replaced by a large set of Tudor accumulators (Müller and Einbach, Hagen) of 1700 ampere-hour capacity. The new battery takes the whole power of one of the two 60 H.P. engines; it is in parallel with the dynamos, and can run 600 lamps for 5 or 6 hours.

The installation of these accumulators increased the capital invested in the station by 15 per cent., and raised the output 38 per cent. Since the erection of this battery the working of the installation gives no trouble at all.

The efficiency of the secondary battery (measured carefully with two Aron wattmeters) was in 1890 as follows:—

January	75 per cent.	July	76 per cent.
February	86 „ „	August	70 „ „
March	70 „ „	September	77·5 „ „
April	80 „ „	October	92·8 „ „
May	74 „ „	(probably an error.)	
June	79 „ „	November	79·2 „ „
		December	77 „ „
Average for the year			78·0 per cent.

The advance made in the efficiency of the former and present equipments is shown by the following:—*

	1887.	1888.	1889.	1890.
Small battery	40 per cent.	52 per cent.		
Large „			78·87 per cent.	78·9 per cent.

* *See* Crompton on Electrical Energy. "Minutes Institution Civil Engineers," Vol. CVI.

The mistake is usually made of including in the total production for the year the energy lost in the accumulators, 20 to 25 per cent. This is by no means right, the percentage loss for the year depending very much on the proportion which the output of the accumulators bears to the total production of the machines. In Dessau, in 1890, the accumulators supplied 52 per cent. of the total output, on which there comes the percentage loss of about 21 per cent., so that the loss in the accumulators only amounts to 10 or 11 per cent. of the total output of the station. The new battery has now been in use uninterruptedly for nearly two years without attention; 20 to 25 per cent. current above the normal output has been taken occasionally, without damage in any way.

The acknowledged advantages of accumulators, as found by experience at Dessau, are that:—

1.—The sudden fluctuations in the light owing to the alterations in the load—which are much greater with small and medium sized than with large installations, on account of the proportionally small total number of lamps burning—diminish very much, as also the pulsations in the light due to the variations in speed of the machines.

2.—With a sudden break-down of the machinery, a part of the supply (such as the theatres, etc.) can still be kept up from the accumulators.

3.—The supplies to the engines have been reduced to the following favourable numbers per horse-power hour:—

(*a.*) Gas consumption for engines, from an average of 31 cubic feet in 1888 to 25 cubic feet in 1890.
(*b.*) The water supply,* for cooling, from 14 gallons to 5½ gallons.
(*c.*) The consumption of oil reduced to half the previous quantity.

4. As the current is ready for use the whole time, day and night, there is no need to run machines during the latter time.

The staff consists of the chief engineer, one assistant, two mechanics, one lines man, and one workman.

The capital expended has increased from £10,000 on 31st December, 1886, to £12,000 on the 31st December, 1890, the cost therefore at the end of 1890, with 3689 lamps, being about 65*s.* per lamp. Of these 3689 glow lamps installed only an exceptionally low percentage is generally burning, viz., 60%. The capital expended, with regard to the cost of the arrangements for gas engines of 100 H. P., could really be smaller.

The depreciation is stated to be as follows:—

For building, 1 per cent; engines and dynamos, 12·5 per cent; accumulators, 10 per cent; switchboard, mains, gas, and water supply, 3 per cent.

The most economical working with the gas engines was that for charging the accumulators sufficiently for one lamp-hour of 16 candles (55 watts) 2·3 cubic feet of gas were required, whilst, according to the previous table, including loss in accumulators and mains, 3·35 cubic feet was the average throughout the year for one lamp-hour. The two results cannot be directly compared, in order to arrive at the

* Because the hours of running at full load were really small.

total loss, because the first figure does not, like the last, represent the average of the whole year.

ABSTRACT OF PARTICULARS.

	1886. (3 Months.)	1887.	1888.	1889.	1890.
1. Number of lamps installed.					
(a.) Glow lamps of various powers	1014	2027	2064	3094	3194
(b.) Arc lamps	4	27	48	56	59
(a.) and (b.) reduced to 16 c.-p. lamps	1076	2400	2544	3565	3689
2. Current supplied in ampere hours	62,827	195,547	243,670	333,380	367,135
3. Gas consumption for year, cubic feet	925,000	1,806,300	2,000,600	2,291,100	2,236,600
4. Average consumption per horse-power hour of gas, cubic feet	..	31·8	30·7	26·6	25
5. Average consumption of water (including that for dynamo bearings), gallons	..	..	13·8	7·4	5·2
6. Consumption of gas per lamp hour (16 c.-p., 55 watts), including all losses, cubic feet.	..	5·08	4·38	3·78	3·35

The average number of working hours of the whole of the lamps installed amounts only to 181, in consequence of the comparatively large number of lamps which are only occasionally burning in the palace at Dessau, compared with 264 for private houses. The number of hours of lighting is therefore obtained in this way by dividing the total year's consumption in ampere hours by the hourly consumption of the whole installation. The average number of burning hours for gas lights—reckoned in the same way as for the electric light—is from 437 to 524 in Dessau, reckoning a consumption of 5 to 6 cubic feet per hour per 16 candle power. The small average number of hours for private lighting of 264 instead of 437 with gas is explained by the fact that the greater part of the consumers use gas and electric light, also that in small towns the best customers (shops and restaurants) do not use artificial light so long as in larger towns, and besides a great part of the customers (the banks and large warehouses) come very little under consideration. The convenience of switching on and off the electric light, and in winter its want of heat, contribute to the lowering of the number of lighting hours. This small average number of hours, which nevertheless could not be placed much higher for electric light in other small and medium sized towns, forms the chief reason of the hitherto poor financial result of the undertaking at Dessau. The number of hours during which light is taken is the chief factor in the earning power, which accordingly could be increased, assuming a higher average.

After the introduction of the accumulators had completely proved their value at

Dessau, the necessity arose for a different arrangement of the machines at the central station. The new arrangement was designed so as to proportion the size of the engines to the load, so that a larger machine would be worked with a large load; for having a light load on a large machine proves very uneconomical in the consumption of gas, as might be expected; also with the original plan of having engines and dynamos of 10, 30, and 60 H.P., the necessity for medium-sized dynamos is lessened very much by the use of accumulators, because a small consumption can be advantageously taken wholly from the accumulators without running any gas engine, or, instead, a large machine can be used and simultaneously charge the battery. Then, in spite of the loss of about 21 per cent in the accumulators, it is more economical to run a large machine in parallel with the battery, than a small engine directly on the mains without accumulators, because, first, large machines need about 25 to 30 per cent less gas than small engines per brake H.P., and, secondly, because the running with accumulators is at full load, whilst the small engines, in spite of their various sizes, are seldom utilized at full load. The size of the machines and their always working fully loaded not only compensate for loss in the battery, but even show a greater working economy, as stated in the previous statistics, over working direct.

The importance of running steam and gas engines, always at their full load, applies as much to central stations as to other works. In the latter case, one is seldom in a position to compare the actual working load on the machine with the actual consumption of gas, whilst in central stations the output can always be ascertained with accurate electrical measuring instruments. With this knowledge, and because in future these observations will be found still more important, Mr. R. E. Crompton introduced a special expression, "load factor." *

In practice, at the Dessau station the 8 H.P. and 30 H.P. engines are occasionally used, not, as formerly, for light loads, but, on the contrary, during the short periods when the 60 H.P. engines with the accumulators are not together able to meet the demand. The four machines must then work together with the accumulators. Whilst in 1886 gas engines could not be obtained generally of over 60 H.P., twin engines can now be had of 120 to 144 brake H.P., so that in place of the three engines of 60, 30, and 10 H.P., a single engine of 120 H.P. could be put up, which, giving 20 H.P. more power, and requiring less room, would in addition need per H.P. less gas, water, oil, and attendance. Then one can, with the large gas engines, obtain such a uniform speed, that, indeed, a single cylinder machine could be coupled direct to the dynamos, so as in future to reduce very much the space formerly required for belts, pulleys, and complicated couplings.

Finally, there is the consideration that with accumulators a starting motor is not required for the large gas engines, as they can be started by the dynamos by means of the current of the accumulators. The manager of the station, Herr Roscher, has employed this arrangement since 1890 in a very simple manner, by means of inserting resistances, and all the usual starting apparatus for the large gas engines is dispensed with. For the above reasons, during the current year the arrangements will be altered so that instead of the present engine a new one of 120 H.P. will be directly

* *See* page 190.

coupled to a new dynamo of Fritsche and Pischon, of a total output of 84,000 watts; one of the 60 H.P. engines will also remain. The accumulator battery—which will be enlarged, as necessity demands, so that it will take for full charging the whole power of the new 120 H.P. engine—will be charged temporarily during the day by the 60 H.P. engine, and during the evening hours the 120 H.P. machine will work at the same time with the accumulators supplying the mains, so that instead of three there will be only one fully loaded machine, and instead of four, in the evening, only two will be at work. It has been found that the capacity of the first battery is actually more than 60 H.P., so that the 120 H.P. engine can really be used to supply about 75 H.P. to the accumulators.

RESULT OF THE FIVE YEARS WORK AT THE DESSAU CENTRAL STATION.

The gas engine undertaking has proved advantageous, and under the supposition that the gas is not purchased, a combined gas and electric light installation is worthy of recommendation for small and medium sized towns, for various reasons.

The advantages which such stations offer are:—(1.) Small ground space required. (2.) Small water consumption—five gallons per H.P. hour, which would be still less with better cooling apparatus. (3.) Avoidance of coal transport through the town. (4.) Absence of smoke. (5.) Small capital cost, as compared with steam engine projects of similar size. Because the ground space is smaller, one can more easily find a suitable site for gas engine than for steam engine installations; this space can be in the middle of the town and in the centre of the district where the electric light is required; also, the cost of a gas installation of over 100 H.P. is less than for similar sized steam engine works including spare boiler, boiler-room, and chimney-shaft. (6.) Less fall of potential in the mains, in consequence of the more favourable situation of the station. (7.) Small amount of attendance required. (8.) Convenience and ease of management, especially for undertakings of medium size, where the fluctuations in the total consumption usually occur suddenly and the time of working is often very short. With unexpected demands for greater supply, gas engines are much more quickly brought into work than when boilers are required. For an accurate comparison with the cost of a steam engine undertaking, the actual cost of the gas must be especially considered.

If a gas works produces a large quantity of gas, for example, 180 million cubic feet, for a single large consumer, viz., the electrical central station, the cost of management is not thereby raised much, only wages, repairs, renewals, etc., come under consideration; also the cost of manufacture per cubic foot is reduced, and the most important share of management expenses, viz., salaries, falls also very much. It has been recently stated that the cost with gas in comparison with steam is completely in favour of the former. Until lately, the cost of large gas engines was always nearly the same as for similar sized steam engines. The reduction in price caused by the expiration of

patents is remarkable, for a 120 H.P. gas engine, including erection, is only about half that of a steam engine, with boiler-house, chimney-shaft, and spare boiler; a double-cylinder 120 H.P. gas engine costing at the present time not more than a 60 H.P. did in 1886. It may very reasonably be assumed that in the course of the next few years still larger gas engines with higher economy will be obtainable, as their size in the last five years has more than doubled; so that in future schemes for central stations one may not only rely on having larger engines but also an actually smaller gas consumption.

THE ELECTRIC LIGHT CENTRAL STATION OF WILDBAD GASTEIN.

CONTINUOUS-CURRENT DYNAMOS DRIVEN BY A TURBINE.

The favourable result, which was obtained with the electric light at the Lainzer Zoological Gardens, was the reason that, in estimating for the Gastein Baths, the General Administration ordered, from the firm of B. Egger & Co., Vienna, an electric light installation for the whole town of Gastein.

The application of steam power was excluded on account of the nature of the place and the trouble and expense of conveying coal. On the other hand, the well-known waterfall of Gastein Ache offered the most favourable opportunity for the utilization of the water power.

It was determined, for the more advantageous application of the water power, to utilize the weir and works which were already in use for working a turbine, so that the cost of the adaptation to the electric light was very unimportant. The deepening of the canal supplying the water had to be undertaken with the greatest precautions on account of the close proximity of hot springs. Also in the execution of this work, on account of the bathing season and severity of climate in winter, only a small part of the year could be utilized. In spite of all these difficulties, the undertaking was finished within a year.

In the year 1887 about 720 16 candle-power glow lamps were required and a single arc lamp. These were partly for street lighting, partly for the lighting of the pump room, together with the Kursaal, as well as hotels and the larger private houses. At the present time the number has increased to 900 glow lamps of 16 candle-power.

On account of the necessity, with respect to the anticipated increase, of keeping within the limits of an economical and paying concern, a maximum lighting of 1200 16 candle-power lamps was fixed on, so that later on a set of accumulators will be erected.

From the quantity of water, approximately 130 gallons per second with a fall of 72 feet, a turbine is worked of 130 H.P., driving four suitable dynamos giving 30,000 watts. One of these dynamos is kept in reserve. From these dynamos are connections to a switch-board, which is provided with the necessary regulating instruments as well

as the requisite switching apparatus for connecting the machines in parallel (all on the Egger system); whilst for the local supply there are three separate distributing boards. The principal mains go from the engine-house underground. They consist of iron-sheathed lead mains, and, after passing the main thoroughfares, are then continued as bare copper cables overhead on poles. Plate XV. shows a plan of the town and the situation of the turbine-house.

The maximum tension for distribution is 130 volts.

It would, perhaps, have appeared better to have erected several small instead of one large turbine. The storage arrangements were only intended to provide for the fear of the filling up of the tail-race with sand at high water. Working at full power is only required for the six months period of the bathing season, so that during the rest of the year alterations or working repairs to the turbine can easily be accomplished.

The installation runs the whole year, in winter the consumption being limited to about 120 glow lamps. The turbine is therefore run at half its ordinary speed (100 revolutions per minute), and lamps are used at a tension of 50 volts only.

The undertaking cost £6,500. During the summer months the cost of a 16 candle-power glow lamp per hour is three farthings, including lamp renewals; during the whole of the winter season only six shillings per lamp per month. After deducting expenses and payment of interest on the capital, the surplus is devoted to the benefit of the consumers to lower the price charged for current.

"KHOTINSKY" SYSTEM.

THE APPLICATION OF THE KHOTINSKY ACCUMULATORS TO CENTRAL STATIONS.

FILIALE GELNHAUSEN, ROTTERDAM.

The Khotinsky accumulator is in its present form the result of years of study and practical experiment. The electrodes are made out of lead plates fitted with T-shaped ribs. These grids when packed form the electrodes, the frame of one being shown in Fig. 65. The illustration represents the grid used for great storage capacity, one having smaller cavities being used when required for rapid discharging. The active material is filled in between the ribs. In the construction of these grids, the principle was kept in view that, on charging, the consequent expansion of the active material of the positive plate should not be hindered. Only thus is it possible to check the buckling of the

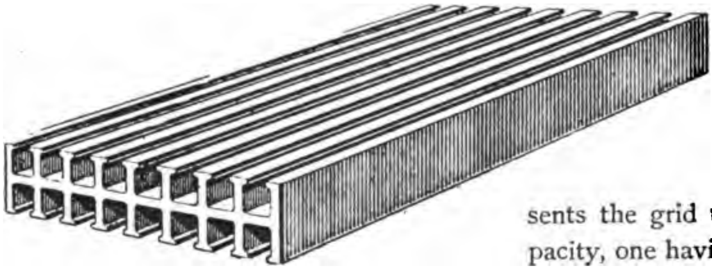


FIG. 65.—LEAD GRID OF KHOTINSKY ACCUMULATOR.

p.96.

electrodes, which in a longer or shorter time must destroy the plates. On the other hand, by means of the projecting ridges of the grid, the active material is, in an efficacious way, prevented from falling out.

The Khotinsky accumulator gives a very considerable capacity per pound weight of electrode. The length of the electrodes can be varied as required, the breadth is always kept the same for all types. Should tall electrodes be employed, several lead grids are soldered over one another a small distance apart. Short lead strips are chosen preferably, because the density of the acid during the working of a cell is always greater at the bottom of the vessel.

These accumulators are employed in the following central stations:—

I. THE ELECTRICAL CENTRAL STATION OF THE TOWN OF RHEIMS.

For this central station a set of accumulators, on the Khotinsky system, was first installed in the year 1888.

Local circumstances, besides want of space, made it impossible to erect the dynamo and engine power in the vicinity of the district of consumption. It was resolved, therefore, to put up the generating station about a mile from the gas works of the company.

The installation, a diagram of which is shown in Plate XVI., consists of two dynamos, of 350 volts tension, in parallel, driven by two gas engines. The current from these dynamos goes to the distributing station, where it is switched on to two sets of accumulators in series; to these two batteries the mains are connected on the three-wire system. In order to obtain the greatest possible economy in the leads, an electromotive force of 150 volts is used. Each battery connects on to the three-wire system, the cells are charged three in series of 58 cells each, and for discharge are joined up as two parallel sets of 87 each.

The capacity of each 150-volt battery is 400-ampere hours; it can therefore run 270 16 c.-p. lamps for four hours at 150 volts.

Two reversing switches are used for charging and discharging; for regulating, as well as for keeping the volts constant during charging, each battery is provided with a resistance, arranged to keep up the required pressure whether one lamp or the whole number are working.

The switching apparatus and measuring instruments are placed on a handsomely equipped switch-board, which is arranged in a simple and efficient manner; and the regulating and switching are worked in a very easy and quick way; so that if the lamps of a theatre are suddenly lighted, the pressure only varies by half a volt.

II. BERLIN STATION (FRIEDRICHSTRASSE) KHOTINSKY SYSTEM.

The connections for this block-station are shown in Fig. 66. DD are the dynamos, the battery is divided into three sets—two of 59 cells and one of 58,

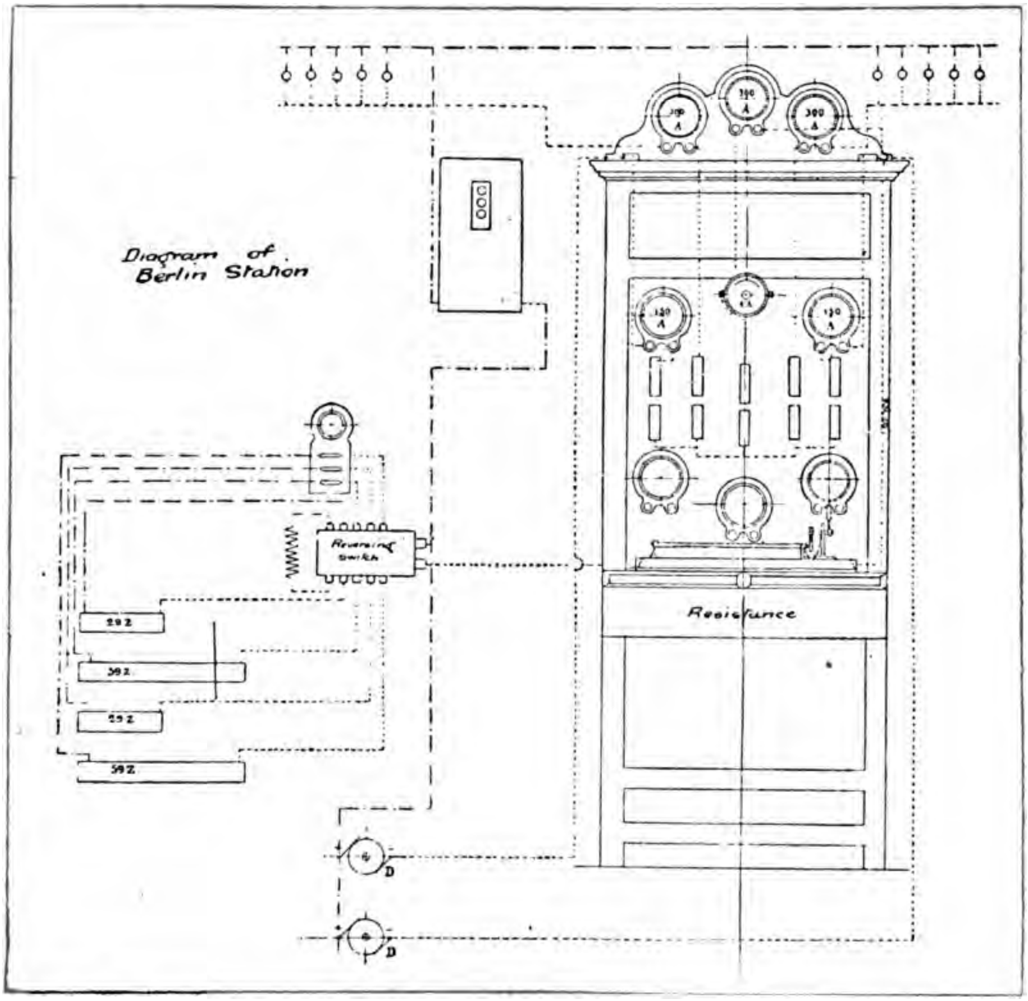


FIG. 66.—DIAGRAM OF BERLIN STATION.

the latter being again split into two parts of 29 each. For charging, the two parts are put in series, and the three sets then in parallel.

For the discharge the battery is made up in two sets of 88 cells each; the output is measured by an Aron meter.

A switch regulates the current from the accumulators by altering the number

of cells and by means of an artificial resistance; above the resistance are placed the other switches and measuring apparatus.

A ten years' contract has been made for the supply of electrical energy for maintaining the following:—

(*a.*) 3 Arc lamps of 1000 c.-p., in series, current required	9 amperes.
270 Glow lamps, 16 c.-p., 150 volts, ·36 ampere current required	98 „
For nine hours per day in winter	107 amperes.
(*b.*) 3 Arc lamps of 1000 c.-p.	9 amperes.
12 „ „ of 500 c.-p. (3 in series, current 6 amperes)	24 „
For six hours per day in winter	33 amperes.

(*c.*) 280 Glow lamps, 16 c.-p., 150 volts, ·36 ampere = 101 amperes for three hours per day in winter.

The consumers' account has to include cost of renewals.

Later on 300 glow lamps, 16 c.-p., 150 volts, ·36 amperes = 108 amperes will be run for seven hours per day in winter.

The generating station is fitted as follows:—

2 Boilers, 45 H.P. each, in one room of	540 square feet.
2 Compound steam engines, 35 H.P. brake each.	
1 Dynamo, 150 volts, 130 amperes, with a reserve space for a similar sized dynamo to be erected later, together in one room of	400 „ „
Accumulators with a guaranteed capacity of 600 ampere-hours, 150 volts constant potential, in one room of	380 „ „
Coal-cellar, one room of	130 „ „
Total space	1450 square feet.

The accumulators are so arranged that they can take plates for more than the 600 ampere-hours guaranteed capacity, which can therefore be increased without fresh space being required.

The cost of the installation was £3000. The complete charging of the cells occupies about eight hours—from 7 a.m. to 3 p.m. After the expiration of three hours, during which 241 amperes are needed, for a further three hours a current is required of 140 amperes. This still leaves about 237 ampere-hours' remaining charge in the cells; so that charging can either be discontinued earlier, or the current used for a light load for another hour. If the reserve in the cells is not needed, the surplus reduces the time of charging by about three hours daily. The employés required are one mechanic and one stoker.

THE THREE-WIRE SYSTEM WITH ACCUMULATOR SUB-STATIONS.

By J. Einstein and Co., Munich.

In central stations for electric lighting, as the cost of the leads must not be too high and the management of the undertaking must be simple, the firm of J. Einstein and Co. have adopted the three-wire system for all their central stations. Even if the cost of the mains has to be placed higher than, for instance, with the five-wire system, still the simplicity of working with only three wires offers such advantages that it is to be preferred. The three-wire system can be adopted either for direct supply or in conjunction with accumulators. When the consumption is for a fixed time, also when there is no great fluctuation in the supply, as, for instance, for street-lighting and similar purposes, the current may be taken direct. A junction is made in the centre of each district to be lighted, from which mains radiate so as to surround the area with a circle of wires with cross connections. In all cases there is very little loss of potential in the distributing network, only amounting to from nothing up to a maximum loss of 1 to 1·5 per cent.; nevertheless, in the feeders from the dynamos to the junctions a considerable fall of potential may be allowed up to 15 per cent. Testing leads are run from the dynamo room to the junction boxes, to show what the tension is at those points. The dynamos are either shunt or compound-wound machines, which in the latter case are over-compounded and give a higher tension to the feeders; so that in spite of the varying supply, the electromotive force at the distributing points remains practically constant.

The stations erected by this firm, of München-Schwabing, as well as in Varèse and Susa in Italy, are after this system.

THE SCHWABING CENTRAL STATION.

The town is divided into four lighting districts, for which there are feeders ½-inch in diameter. In these there is a fall of potential of 10 per cent. = 12 volts, in the distributing rings a similar fall of 1·6 per cent., equal to 1·5 volts all round. The single rings are again connected by balancing mains, so that with varying loads there is practically the same potential for all the lamps.

The mains are supplied on the three-wire system, but switches are provided so that in the event of a break-down to one machine the corresponding switch is turned, by which the mains are run by the other machine as in a two-wire system. For the arc lamps which have been installed there are other leads and switches, so

that the lamps can be connected to either dynamo, besides these there are resistance switches, which can be used if, in the night, the electromotive force, and consequently the lighting power, of the glow lamps should fall.

The motive-power is furnished by a 40 H.P. gas-engine, using gas manufactured on the Dowson system. There are 10 arc lamps of 1000 candle-power (nom.) each, 30 glow lamps of 32 candle-power each, and 170 glow lamps of 16 candle-power each. All the wires are carried overhead, as for such a district it would have been too expensive to place them underground.

The whole plant was tested, and gave the following results: When the engine was loaded the variations in speed were under one per cent., and the light of the glow lamps was practically constant. A brake test of the engine showed that it was actually capable of developing fully 60 effective H.P. Owing to there being an insufficient supply of water for the brake, long continuous trials were not possible, but it was proved that the total fuel consumption (including that consumed in the boiler) was considerably under the guaranteed allowance of 1 kilo (2¼ lbs.) per effective H.P. per hour. The actual figures were 600 grams of anthracite and 100 grams of coke, equal together to 700 grams (1½ lbs.) per brake or effective H.P. per hour.

It is estimated that if the engine had been worked with the town gas of Munich, the cost would have been 12 pfennige (1½ pence) per H.P. per hour, and that with the Dowson gas it is 50 per cent. cheaper. It is further concluded that a large gas engine driven by Dowson gas can compete successfully with a good steam engine.

In order to be able to control the working of the arc lamps from the machine room, each main is provided with a small current indicator of Kohlrausch's system (Hartmann and Braun). In the centre of the switch-board there is an earth tester, in order to be able at any moment to test the insulation of the mains. On the two sides of this are placed two voltmeters, and at the sides of the switch-boards are placed the regulating resistances for the two dynamos. If the central station can without too high a cost be placed within or, at any rate, not far from the lighting district, the machine and accumulator stations can be united. The labour and attendance in this case are small, because the same attendants serve for cells and dynamos, which then work together on to the feeding point situated in the centre of the lighting. If, however, the current is required at a considerable distance from the machines, it becomes advisable to have the accumulator station in the centre of the district connected with the station outside the town by small mains, that it may be so arranged, for example, if the cells are required to give 100 amps. for five hours, they can be charged with fifty amps. for ten hours. Besides the saving in mains, this has the further advantage that a smaller dynamo is needed, and the steam power is utilized to a greater extent; on the other hand, this arrangement is not so simple, because there must be attendants at the accumulator station as well as at the generating station.

If the lighting district is more widely extended, more accumulator sub-stations are employed, all supplying the same distributing network.

THE BAD KÖSEN ELECTRIC LIGHT STATION.

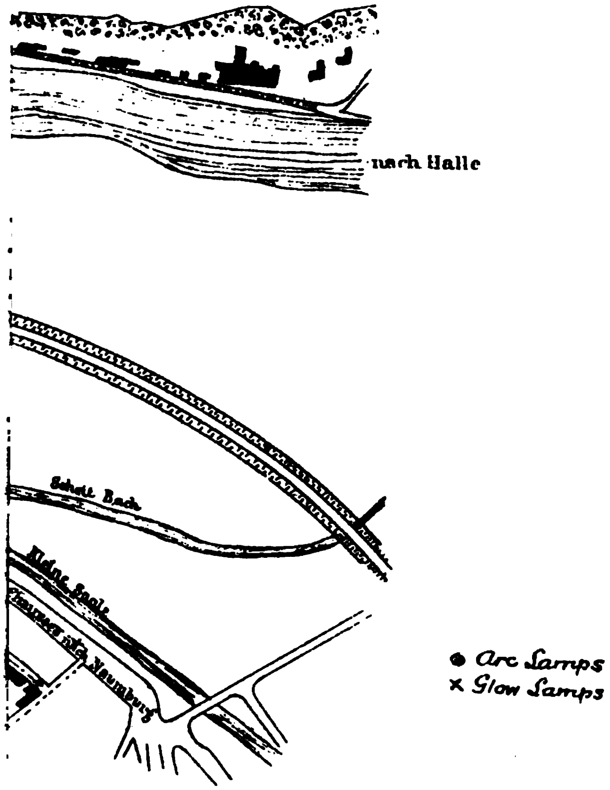
DIRECT CURRENT WITH ACCUMULATORS—POWER FROM THE RIVER SAALE.

BY THE FABRIK FÜR ELEKTROTECHNIK UND MASCHINENBAU, BAMBERG.

The town of Bad Kösen, through which the Saale flows as shown in the plan of the town (Plate XVII., Fig. 1), has a water power available to the extent of 20 to 40 H.P., which has been utilized since 1889 by the establishment of an electrical station. The station is not in the centre of the town, but close to the mouth of the "Little Saale." Figs. 2 and 3, Plate XVII., show plans of the accumulator and engine-rooms, and Fig. 4, Plate XVII., the electrical arrangements of the station, with the dynamos I. and II.

A new turbine was erected, to drive, by means of two friction clutches, two dynamos of 150 to 160 volts each, giving 24,000 watts. The speed of the turbine is 200 revolutions per minute. One dynamo is compound wound, and supplies the street lighting; the second, shunt wound, is used for charging the accumulators, and in the evening runs the private lighting in conjunction with the cells. The set of accumulators consists of 83 cells, Type IX. of the Hagen Accumulator Manufactory, having a capacity of 270 ampere hours, and will run 135 glow lamps for five hours at 150 volts. In order that the expense for copper in the mains to the town might be kept down, a voltage of 150 to 160 was decided upon. In the glow lamps, this was not used at first, on account of the somewhat higher price of lamps than those of 100 volts; the price for 150 volt lamps has not fallen, but the lower pressure has been very satisfactory. With a good supply of water, and using the accumulators, an output of about 33,000 watts can be obtained, sufficient for 600 16 candle-power glow lamps. There are about 400 glow lamps and 20 arcs (6 ampere) in use, which are never all burning simultaneously, twelve of the arcs for public lighting being only used on special occasions. The accumulators are only employed when the water supply fails, being then charged in the daytime. The mains from the dynamos are connected to two bars with four switches on each, four of these serving for the street lighting and the remaining four for private lighting. On the switch-board there is also a switch for connecting both divisions of the lighting to one machine, or to the cells. The turbine house is next to the dynamo room, so that the regulation of the sluices can be effected by means of a hand-wheel close to the dynamos. A room was built above for the secondary batteries, which are provided with a multiple switch for regulating the voltage, the switch-board being so equipped with the necessary apparatus that the working is extremely simple; two men look after the charging of the cells and the supply at night. The mains are overhead, the insulators being placed chiefly on wooden poles. The cables for crossing the Saale were originally on the bridge, but this having fallen, owing to the high water of last year, the means of crossing had to be re-arranged. This work had to be done under great difficulties and during

Plate XVII.



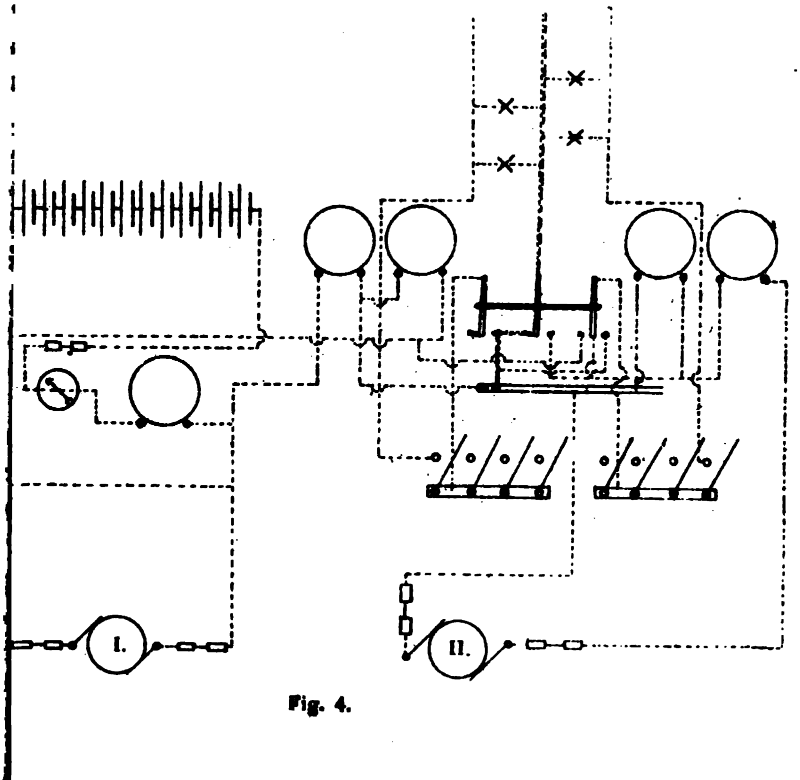


Fig. 4.

extreme cold. There were carried over twenty copper wires, 6mm. (·24 inch) diameter and 200m. (220 yards) span; these are not in tension, but hang from two 10mm. steel wire ropes fastened to poles, 40 feet high, on the two banks.

The cost of the undertaking, without the turbine but including the accumulators, was £1,500.

The cost of working is about the same for half and full load; no meters are employed, an arrangement being made with each consumer. Taking an average load of 400 lamps, for 600 hours per annum, gives a total of 240,000 lamp hours; the cost of working for the year is:—

	£	s.
For oil and cleaning materials	17	0
For repairs and consumption	37	10
For wages, &c.	73	0
For sinking fund	131	10
Total	£259	0

One lamp-hour therefore costs ¼*d.* per 16 c.-p. lamp.

The street lighting consists of 110 glow lamps and 12 arcs. The cost for lamp renewals and carbons is £27 10*s.* per annum.

THE BAMBERG CENTRAL STATION.

IN CONNECTION WITH THE WATERWORKS.

A complete station is not yet erected, the present installation, dating from 1889, only utilizing a part of the water-power available in the centre of the town.

Bamberg is intersected by the Regnitz, the so-called Altwasser, and the Regnitz canal, the latter flowing through the old town. By means of weirs, the water power is utilized for various industrial purposes. A number of mills are erected on the island formed by the New Regnitz and the lock canal; on the other shore of the New Regnitz, at the Stanwehr, close to the Town Hall, are the town waterworks, where the central station is placed. On the island there is also a reserve sub-station, Plate XVIII., Fig. 7; at the reserve pumping works, between these two stations, there is a mill belonging to the town, with 80 to 90 H.P. available. Originally, it was intended to light the streets only, but as there seemed a likelihood of current being wanted for private lighting, provision was made for this also. At the waterworks there are two dynamos of 6000 to 7500 watts, driven, by means of a countershaft on which there are two friction clutches, from a water wheel, foundations being also ready for two more dynamos. The current from these machines is taken to the switch-board, shown diagramatically in Fig. 8, Plate XVIII. In the reserve pumping station there are two dynamos of 12,000 to 15,000 watts, driven from a gas engine of 40 H.P.;

the current from these machines is also taken to the switchboard in the waterworks. There is, therefore, available 36,000 watts, and with the water wheel about 75,000 watts.

In the immediate vicinity of the waterworks there is available about 80 to 90 H.P. in the Leibel Mills. It is intended to erect here one or two dynamos of 60,000 watts, the whole station then giving 135,000 watts; also to put up a set of accumulators in the mills, so that, without the gas engine, which would form a reserve, 3000 glowlamps of sixteen candle-power could be supplied.

In Plate XVIII. are shown the two existing stations (scale 1 in 180) and a plan of part of the town (scale 1 in 11,900).

The leads, on the three-wire system, are run over the houses on iron poles. This has proved satisfactory up to the present, but for private lighting underground cables will be laid, which extension will not take place until the Leibel Mills are provided with electrical plant. Each dynamo gives 110 to 115 volts, two arc lamps being run in series; there are altogether twelve pairs of arcs, taking 10 amperes. In each of the large buildings supplied, there is a hand regulator for controlling the voltage. The waterworks supply the street lighting of 24 Essberger differential arc lamps; the reserve pumping-works form a reserve for the street lighting, being besides used for theatre lighting (500 glow lamps) for 60 evenings in the winter. The Leibel Mills alone, with accumulators, would run the private supply (2500 glow lamps). The mains all go to the chief switch-board in the waterworks, so that one man can regulate them; besides this, a man is required for the machines in the waterworks or the pumping station, and later on, when complete, another for the Leibel Mills.

The dynamos I. and II. (Plate XVIII., Fig. 8) are in series, and connected to the mains through the switches (U_1.) and (U_2.); if required, the machines III. and IV., driven by the gas engines, can be substituted. These last two machines supply the theatre. H_1, H_2, H_3, Fig. 8, are the supply mains.

In the Town Hall there is a small battery of 60 accumulators, charged from the dynamo (I). When extended, there will be another dynamo (V) and accumulators (Li. and Lii.). On the switch-board there are 20 switches for the town supply; each dynamo is provided with a voltmeter.

The cost of the undertaking, as it is at present, with four dynamos and 24 large arc lamps, including wiring and the accumulators in the Town Hall, fittings and erection, has been £1200; buildings and machines for the motive power were ready at hand previously, it being only necessary to make some slight alterations at a cost of £300.

Only one extra workman was required for looking after the 80 glow lamps and 24 arcs, the current supplied being as follows:—

Glow lamps, 30 amperes at 110 volts = 3300 watts for 1200 hours in the year (12 lights for the Town Hall clock burn the whole night) =	3,960
24 arcs, 10 amperes, 110 volts per pair = 13,200 watts for an average of 1800 hours = ...	23,760
Kilowatt-hours	27,720

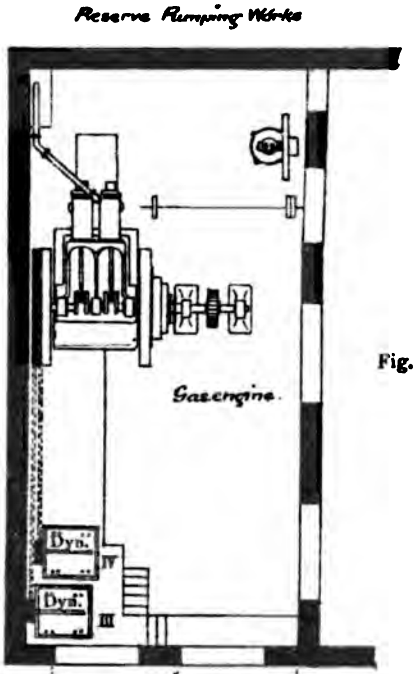

Reserve Pumping Works
Gasengine.
Dyn.
IV
Dyn.
III

Fig. 7.

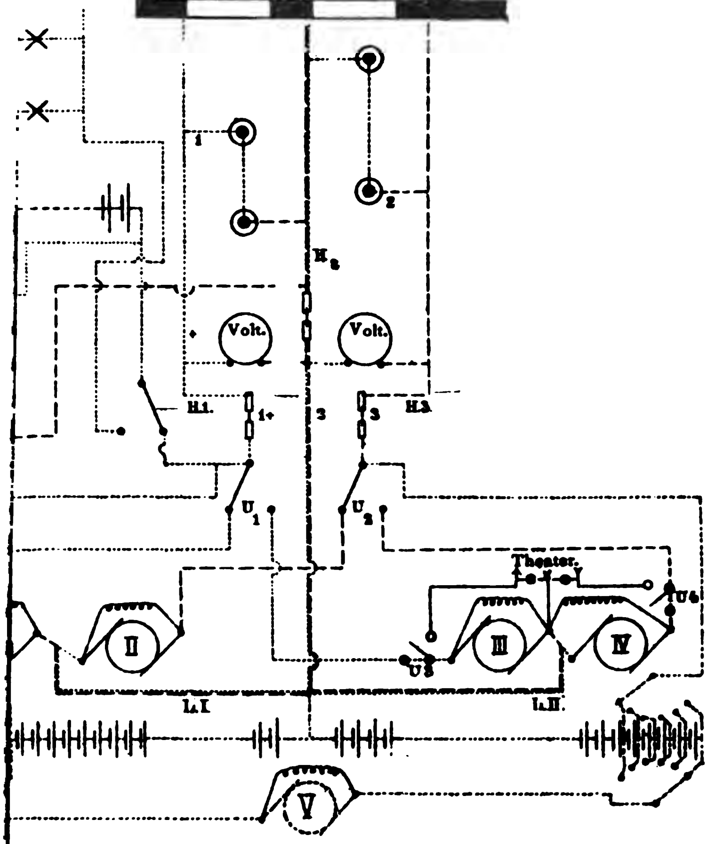

1
2
H2
Volt.
Volt.
H.1.
1+
3
3
H.3.
U1
U2
Theater.
U6
II
III
IV
U3
L.I
L.II.
V

Fig. 8.

EXPENSES.

	£	s.
Engineer's salary	77	0
Carbons	75	0
Oil and cleaning materials	6	0
Maintenance of machines, mains and lamps	17	10
Looking after machines and lamps	67	0
Workmen's Sick Fund and Insurance	2	10
Sundries	24	0
Sinking fund	46	0
Total	£315	0

One kilowatt hour therefore cost 2·73*d.* Deducting £100 for carbons, glow lamps and arc lamp trimming, 1000 watt-hours cost 1·86*d.*, or the current for a 16 c.-p. lamp, ·087*d.* per hour. In this the cost of buildings and motors is not included, as these were already at hand employed for other purposes.

III. THE GEVELSBERG STATION.

THREE-WIRE SYSTEM WITH ACCUMULATORS.

Gevelsberg, a town of about 10,000 inhabitants, situated in the valley of the Ennepe between Elberfeld and Hagen, is not suitably adapted for an electric light project, as it extends for a distance of four miles, and is very narrow, two-thirds of the whole town consisting of a single street, the Hagenerstrasse. This situation naturally demanded a comparatively large expenditure for copper mains, which were arranged so that the loss of electromotive force was 10 volts in the feeders and two volts in the distribution mains.

The plant, which was erected in November, 1890, was originally designed for an equivalent of 4000 16 c.-p. lamps, machines being first put up sufficient for 1120 lamps burning simultaneously. For this there were erected two Kuhn condensing engines of 60 nominal H.P. each, and three shunt-wound dynamos, one of 40,000 watts, the others of 20,000 watts each; these were used with two sets (66 each) of Tudor accumulators, of 700 ampere-hour capacity and 140 amperes maximum load. The small dynamos can, if necessary, be loaded up to 30,000 watts. The two sets of accumulators are charged in parallel by the three dynamos; the total voltage of the cells varies from 320 to 240 volts during discharge. The 1120 lamps of 16 c.-p. require 560 amperes at 120 volts or 67,200 watts, including the loss in the mains. The two batteries will give 140 amperes at 240 volts = 33,600 watts, their capacity being 700

ampere-hours; the output of the three dynamos is 80,000 watts. There is, therefore, a reserve power of 100 per cent., one engine being sufficient. The dynamos and accumulators together will run 2000 lamps. The distribution circuits are arranged on the three-wire system; the current is taken by means of four feeders to six distributing points (the total fall of potential at full load being 10 volts), to the supply mains, in which there is a maximum loss of two volts. All the mains are run overhead on wooden poles, which are impregnated with corrosive sublimate as a protection against rot.

For street lighting, 50 candle-power glow lamps are used in series. The street lighting can be arranged to suit the different loads at the distributing points; but it is intended to put the four glow-lamp circuits in series, for which purpose a continuous-current transformer will be used to raise the voltage from 110 to 440. Besides these lamps, there are for public lighting of squares, etc., eight Essberger arc lamps. The charging current for the accumulators is regulated by hand with two multiple switches, the discharge being controlled by two automatic switches; three other automatic switches prevent the reversal of the current from the battery during charging. Each feeder is provided with an ammeter and testing wires, run from the distributing boxes to the switch-board, for regulating the electromotive force at the junction with the mains, which is effected by means of resistances, the board being so arranged that the connections at the back are easily got at. The maximum distance of any lamp is about four and a quarter miles; about 28 tons of copper were employed for the mains. There are at present about 1500 glow lamps and 16 arcs.

Plate XIX., Fig. 9, shows a plan of the town, scale 1 in 120,000 ("Elektrische Centrale" indicates the position of the generating station); Fig. 11, Plate XIX., the ground plan of the station buildings, scale 1 in 300; and Fig. 67 gives a view of the switch-board.

The charge per lamp-hour (16 candle-power) is one halfpenny, with reduction for large supplies. During the daytime motors are supplied, of which there are now many working; for these the price for current has been considerably reduced.

The charging of the accumulators is commenced in the winter at half-past two, in the summer at a suitably later hour; on many days there is no charging required. The machines are run until 11 o'clock. In the winter the employés do not have to work more than 10 hours; the staff consists of a manager, fitter, mechanic, and a stoker.

The cost of the undertaking has been as follows:—

	£		£
Engine house, including foundations, reservoir, chimney and preparations for the boiler	2250	Brought forward	4850
Steam engine with erection	900	Switch-board	350
Boiler " "	650	Accumulator with erection	1400
Pumps, pipes, &c.	350	Cables	2250
Dynamos	700	Street lighting	350
		Telegraph poles and insulators	300
		Erection	400
Carried forward	£4850		£9900

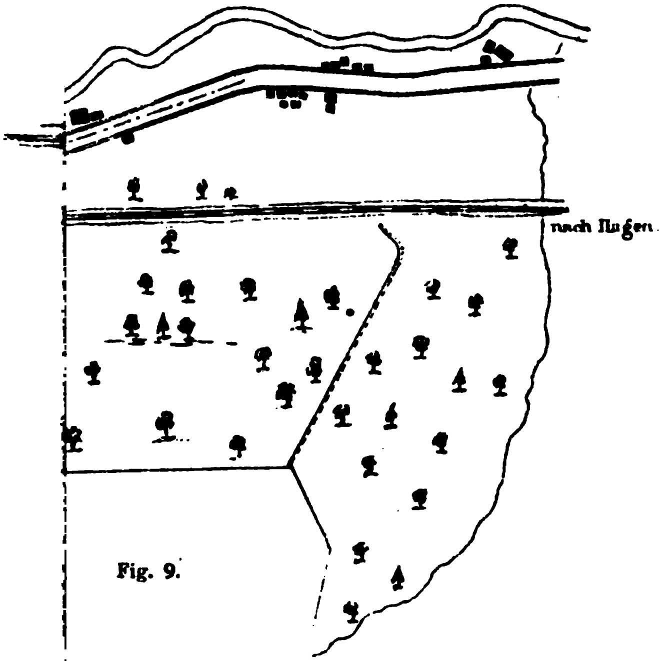
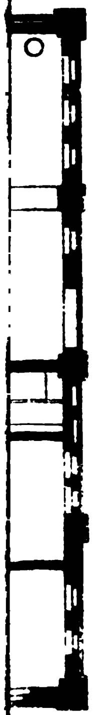


Fig. 9.



Arc Lamps
Glow Lamps
Distributing centres

It should be stated that the first cost of meters and electro-motors was defrayed by the town, the consumers now paying a rent for them.

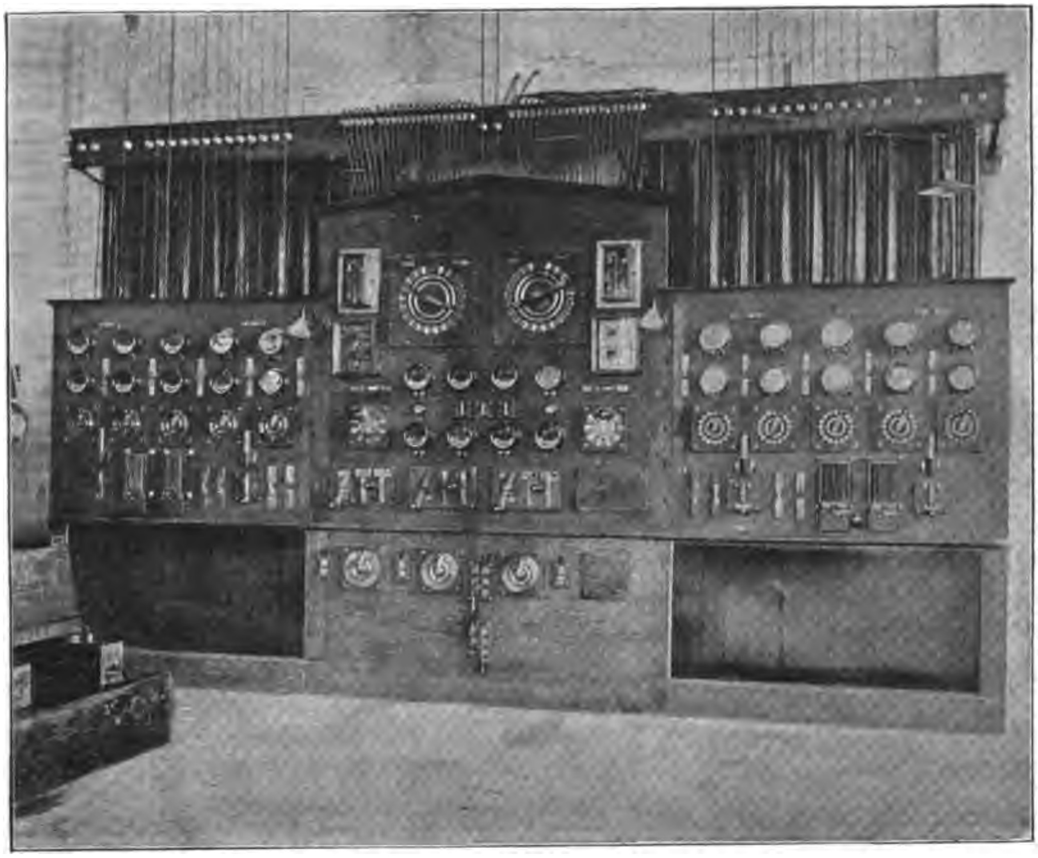


FIG. 67.—SWITCH-BOARD, GEVELSBERG STATION.

LIGHTING OF THE BAMBERG RAILWAY STATION.

MOTIVE POWER STEAM.

The railway station is lighted by

18	Arc lamps,	16	amperes,	Essberger's	differential.
6	"	12	"	"	"
30	"	6	"	"	"
20	"	5	"	Wehr lamps.	

All indoor lighting is done by glow lamps, of which there are altogether 800. The working electromotive force is 125 volts, the total current being 700 amperes. A special building was put up, consisting of a machine-room, boiler-house, two floors for accumulators, store-room, and repairing shop. Two Heine patent boilers are used, having each 940 sq. feet heating surface, and working at a pressure of 150 lbs.; a third similar boiler remains in reserve. In the boiler-house there is a feed-water heater and a Dehne filter for purifying the water supply. In the machine-room are two 60-70 H.P. compound steam engines, with a third in reserve, made by the Nuremberg Fabrik der Maschinenbau; these machines, which run at 140 revolutions, drive by belting three shunt-wound dynamos of an output of 360 amperes at 125 volts. To supplement these, and to provide for the day lighting, there are 66 cells of the Hagen Akkumulatoren Fabrik, which will give an output of 221 amperes, having a capacity of 735 ampere-hours. The normal load of the two dynamos is 90,000 watts, or with the accumulators 116,962 watts; the maximum output the station could give amounts to 160,000 watts, sufficient for 2700 glow lamps. The current from the dynamos is taken to a marble switch-board, there being another for the accumulators; the dynamos can, by means of switches, be connected to the battery or direct to the mains. On the switch-board are two main distributing bars, to which are connected six regulating switches for the railway post office, the goods-room, locomotive shed, workshop, waiting-rooms and offices; over each regulator is a voltmeter, showing the electromotive force in the various buildings. As the accumulators were installed later, the regulating apparatus for them could not be put on the same board, the current from each machine passes through a direction-indicator and an ammeter.

The arc lamps for out-door lighting have a separate switch-board and regulating resistance; there is also in the porter's room another switch-board, with eight resistances for the platform lighting. The 16-ampere lamps are mounted on lattice-work masts 60 feet high, the 12-ampere lamps on poles 40 feet high; those for lighting the station yard hang from cast-iron standards 40 feet high.

As the undertaking has been at work only a short time (since June, 1891), it is impossible to give cost of maintenance. One fitter, two mechanics, two stokers, and two workmen are employed for attending to the arc lamps. The accumulators are

charged to the required amount in the evening, not being generally used to supply current when the machines are running, but remain charged as a reserve and for supplying about 100 glow lamps in the daytime.

COST OF PLANT, &c.

	£
Engine-house, foundations, drains, reservoirs, chimney	1850
Steam engine, boiler, pumps . .	2650
Pipes	500
Belting	50
Dynamos	600
Carried forward	£5650
Brought forward	5650
Switch-board, complete with apparatus .	500
Accumulators	900
Installation of glow and arc-lamps, including candelabra, poles, &c., and cost of erection	3000
	£10,050

DESCRIPTION OF CONTINUOUS-CURRENT INSTALLATIONS AT BERLIN, ELBERFELD, DARMSTADT, THE HAGUE, STETTIN, BRESLAU AND PARIS, AND SYSTEM OF CONCENTRIC MAINS.

By Siemens and Halske, Berlin.

The firm of Siemens and Halske have generally adopted the three-wire system of Hopkinson, as being the most suitable for distributing electricity to a radius up to 1,600 yards from the central station; one advantage in its favour is that the working of the telegraph and telephone lines is not affected.

Within the last few years this system has been perfected by the adoption of secondary batteries. By use of these, without materially altering the simplicity of working, the machines can be better utilized and the attendance required lessened; and by the erection of accumulator sub-stations, the district lighted can be extended to distances which could not otherwise be economically supplied. In circumstances where the district supplied was very large, or when it was necessary to place the generating station at a distance, a five-wire system has been employed with very satisfactory results, such being suitable for supplying districts with a radius up to a mile and a half.

The annexed Fig. 68 shows diagramatically the various methods used, with and without secondary batteries and equalizing dynamos; these different systems are employed in the following towns:—

A.—Parallel system: Berlin (Markgrafenstrasse Station), La Coruna.

B.—Parallel system, with secondary batteries: Salzburg, Lyons, Toulon, Montpellier.

C.—Simple three-wire system: Berlin (Mauerstrasse Station, Schiffbauerdamm, and Spandauerstrasse), Elberfeld, Helsingborg, Malaga.

D.—Three-wire system, with one dynamo and secondary batteries: Mulhausen, Stockholm, Sundswall.

E.—Three-wire system, using two dynamos: Vienna (Mariahilf), Darmstadt, The Hague, Stettin, Breslau, Copenhagen.

F.—Five-wire, with equalizing dynamo: Trient.

G.—Five-wire, with equalizing dynamo and secondary batteries: Paris (Place Clichy).

H.—Five-wire, with two generating dynamos: Vienna (Neubad).

This firm exhibited at the Frankfort Electrical Exhibition almost every system which they had in use; one of the most notable exhibits is the direct-current machine, which is said to be the largest yet built for the production of such currents. Fig. 69 represents this machine driven by a powerful steam engine. It is of the inside pole ring type, known by the company as J. In this class of machine the number of poles varies from four to twelve, and they are placed in the form of a star inside the rotating armature. The brushes, which are always of the same

number as the field magnets, take off the current from the outside of the armature winding. The armature itself consists of an iron ring wound with insulated copper wire or bars, and it is either provided with a commutator, or the brushes rub upon the outside of the ring itself. The special machine illustrated is designed for an output of 330,000 watts at 150 volts when running at 65 revolutions per minute, and its maximum output at 100 revolutions is 600,000 watts. As previously remarked, it is supposed to be the largest direct-current machine yet built, and the object of the

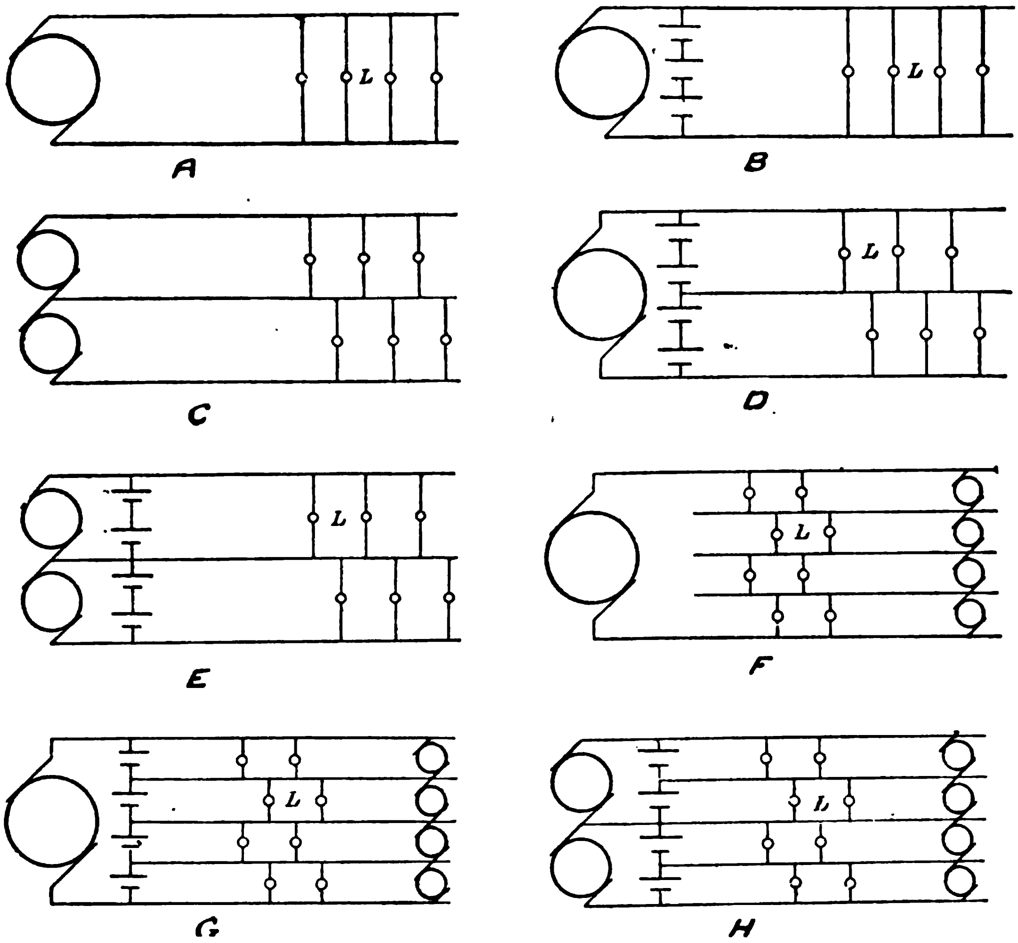


FIG. 68.—DIAGRAMS OF SYSTEMS OF DISTRIBUTION.

makers has been to produce a type of machine of which the fewest possible number would be needed in a large central station. The opinion of English engineers, on the contrary, is distinctly in favour of smaller units, which can easily be loaded to their full output; and, with the exception of the large Deptford station, this idea has been carried into practice in all the large metropolitan stations. The machine shown in Fig. 69 has ten poles, and the armature has an outside diameter of 9·85 ft., while the field magnet cores have a diameter of 8·9 ft. The brushes make contact with the outside of the armature itself. The machine is coupled direct to a triple-expansion condensing

engine of the inverted vertical type, built by G. Kuhn, of Stuttgart-Berg. The cylinders have diameters respectively of 1·64 ft., 2·36 ft., and 3·95 ft., with a stroke of 1·97 ft. The engine is designed for an initial steam pressure of 150 lbs. to 180 lbs. per square inch, and for 120 revolutions per minute. It develops at 80 revolutions 400 brake horse-power, at 100 revolutions 500 brake horse-power, and at 120 revolutions 600 brake horse-power. The high-pressure cylinder has piston valves, with an expansion valve acted upon directly from the governor, while the middle and low-pressure

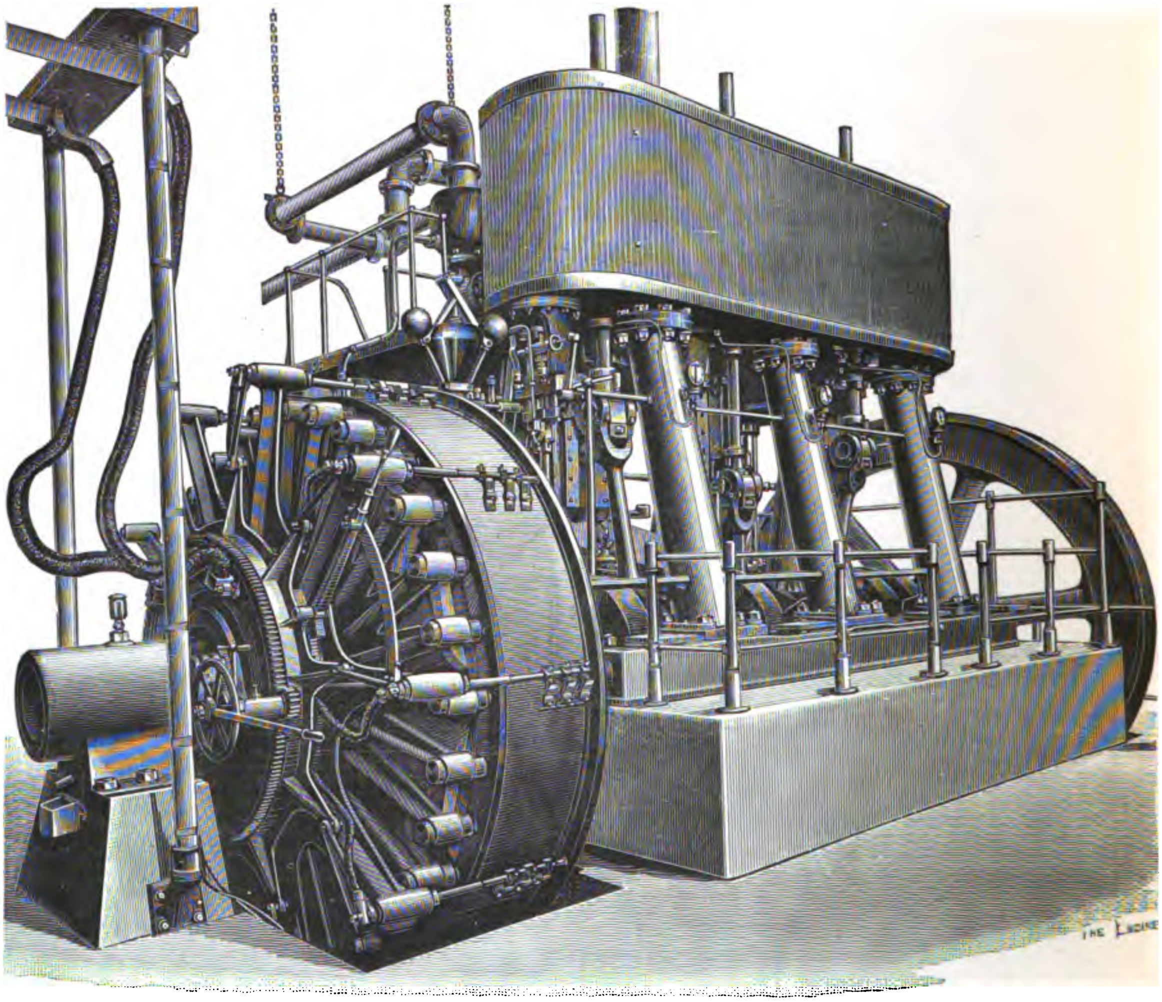


FIG. 69.— CONTINUOUS-CURRENT DYNAMO BY SIEMENS & HALSKE.

cylinders have ordinary valve gear, with balanced slide valves ; all these cylinders are steam jacketed, and a tachometer is fitted to the engine.

Still keeping to the direct-current plant, we next find a dynamo of somewhat similar type, with an output of 35,000 watts at 150 volts when running at 330 revolutions. This machine has an armature of 3·05 ft. diameter, while the diameter of the pole pieces is 2·62 ft. It is provided with a commutator upon which the brushes

rub, and each opposite pair of brushes are coupled together. The machine is coupled direct to a steam engine, built by Messrs. Daeval, of Kiel, which is intended to work with an initial steam pressure of 120 lb. per square inch, and when running at 330 revolutions per minute develops 60 brake horse-power. The cylinders are respectively 9 in. and 14·6 in. diameter, with a stroke of 7·9 in.; the governor is of the Proell type, and coupled direct to the main shaft of the engine. Separate parts of a similar machine

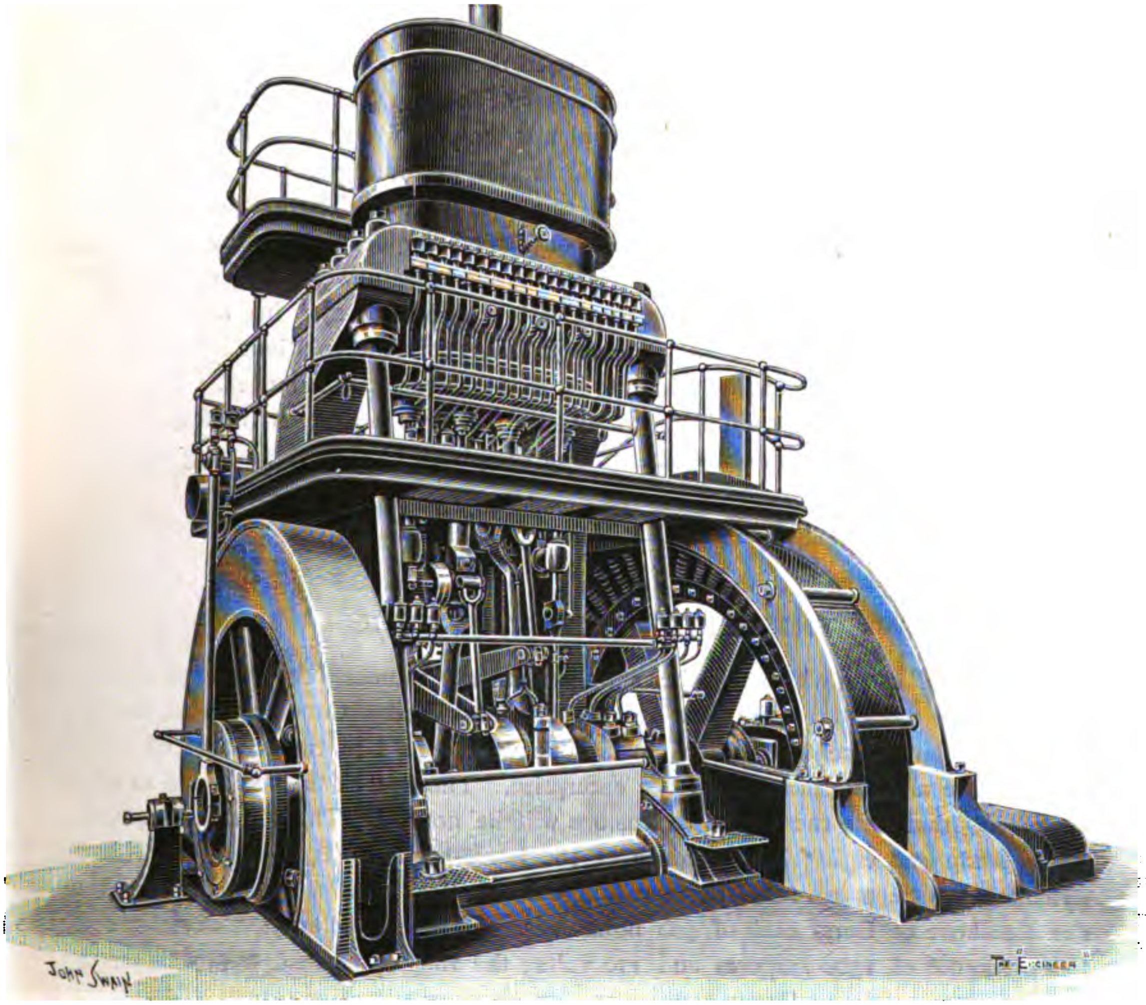


FIG. 70.—ALTERNATING-CURRENT MACHINE BY SIEMENS & HALSKE.

were also exhibited. Seven shunt-wound machines for 150 volts were also shown, the armatures of which revolve with a surface velocity of 46 ft. per second. Three other shunt-wound machines for 65 volts were also shown, in which the armature revolves with a surface velocity of 65·5 ft. per second. All the latter machines have drum armatures, the cores of which are of sheet-iron plates wound with copper wire in such a way that the wires run from one end of the drum to the other end; they are crossed over and return parallel to the first line and end upon the next commutator strip from which

they started. Other-direct current machines, known as the O type, were shown ; in this type the poles are outside the armature, which is of the ring-type, the field-magnet core windings are at the side of the armature, while the pole pieces are of curved form.

The plant for the production of alternating currents consists, first, of a large alternator, shown in Fig. 70. This is known as the makers' Q type, and develops 330,000 watts at 2000 volts when running at 100 revolutions. It is similar to the original type of machine built by the firm. The field-magnet ring consists of 60 bobbins, which rotate inside the stationary armature, which has the same number of coils. Recent improvements are stated to have much improved the output. The outside diameter of the rotating field magnets is 12·2 ft., while that of the armature is 15·1 ft. The field magnets are excited by a direct current, which is brought from the main switch-board. With a stationary armature, such as is used in this machine, good insulation for 2000 volts is more easily obtained than when the armature rotates. The machine is coupled direct to a vertical high-speed compound condensing engine built by the Maschinenfabrik Buckau-Magdeburg, which develops 450 brake horse-power. The cylinders are respectively 24·5 in. and 27·5 in. diameter, with a stroke of 27·5 in., and an initial pressure of 150 lb. per square inch. The engine runs at 100 revolutions. The special advantage of this type of engine is said to be that it is perfectly balanced. The small and heavy high-pressure piston is almost exactly the same weight as the low-pressure piston. The valve gear of both cylinders is of the piston form, with packing rings.

THE BERLIN CENTRAL STATION.

The installations which together supply electricity to nearly the whole of the city of Berlin are worked by the Berliner Elektricitäts Werke Company, who, besides owning the largest central stations in Europe with regard to the number of lamps supplied, are also the pioneers of the enterprise. These stations have been so often described,* that only the recent extensions will be noticed. The Markgraferstrasse, which comprised eight Kuhn engines of 180 horse-power each, working 16 Edison dynamos, has been increased by four compound vertical condensing engines by Van der Kerchove of Gand, each of 400 horse-power. These four engines work directly four dynamos of 1500 amperes and 110 volts; the ring of these dynamos is on the Gramme type, outside the inductors, and is about six feet six inches diameter; the number of revolutions is only 86, but sufficient peripheral speed is obtained owing to the large diameter of the armature. The current is collected by 10 brushes. These engines are splendid examples of the Corliss compound tandem type, and work with economy that it would be very difficult to beat either here or in the United States. Fig. 71 gives a side elevation of the Kerchove engine and dynamo which was made by the Berliner Elektricitäts Werke Company. Fig. 72 shows a photograph of the four engines and dynamos.

* "Some Electric Lighting Central Stations." Prof. Geo. Forbes. Vol. XVIII. "Journal Inst. Elect. Engineers," and "Central Station Electric Lighting." Hedges.

Other extensions have taken place as follows:—

		Area occupied.
I. Mauerstrasse,		
	Four engines of 1000 H.P., with generators .	1044 square metres.
II. Schiffbauerdamm.		
	Six engines of 1000 H.P., with generators .	1759 „ „
III. Spandauerstrasse.		
	Four engines of 1000 H.P., with generators .	572 „ „

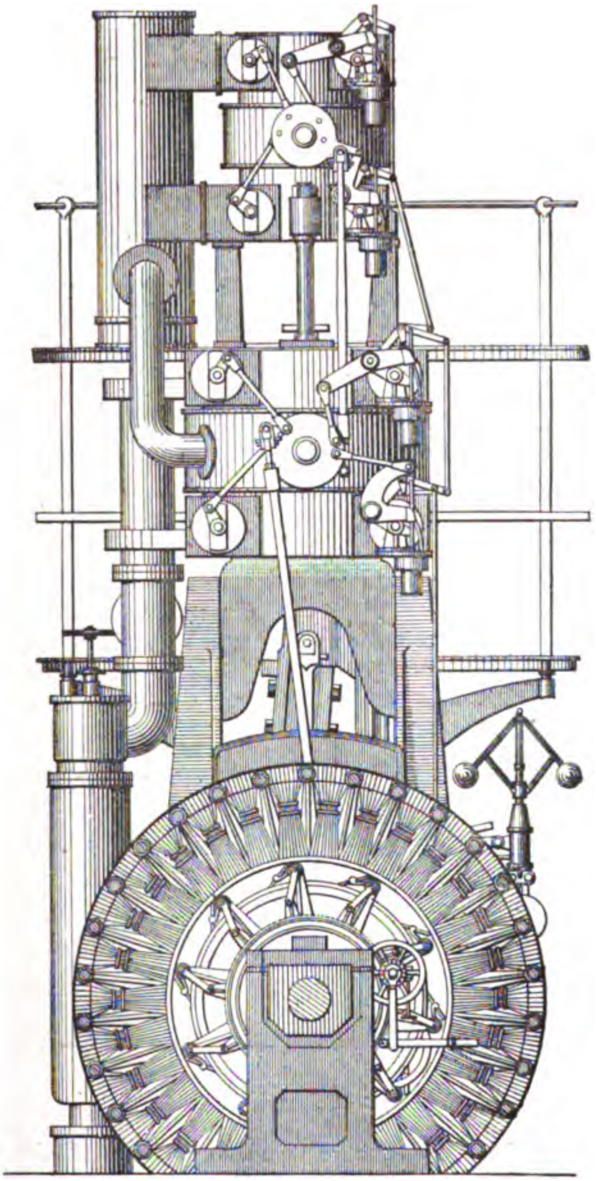


FIG. 71.—KERCHOVE ENGINE AND DYNAMO.

During the past business year, up to July 1st, the number of consumers increased

from 872 to 1314, or about 50 per cent., whilst the corresponding number of lamps, reckoned by the current used, increased from 74,959 to 104,100.

As regards the situation of these stations, the principal consideration has been to place them as central as possible in the area to be lighted. The foundations

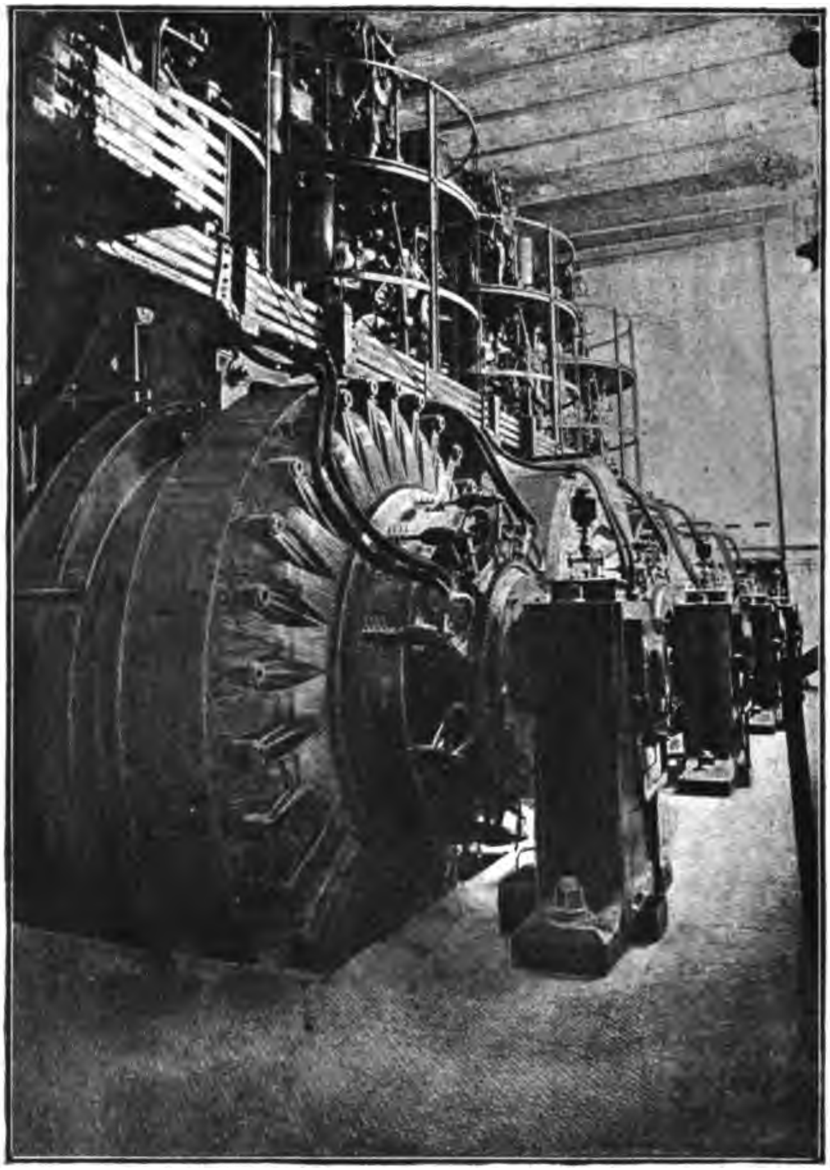


FIG. 72.—ENGINES AND DYNAMOS, BERLIN.

of the engines are so fixed that there is no vibration. Only anthracite coal is employed, to avoid all smoke; and, what is very important, all the coal and ashes are carried after ten at night. The area over which the network is distributed is about 50,000 square metres; the cables are all of Siemens and Halske's make,

and are concentric, with an outside covering of lead, a full description of which is given at p. 136.

No sole concession is given to the company, who simply have the right to take up the pavement and cross streets, and for this permission they are bound to furnish any consumer in the district with a constant supply of electricity at the following charges:—

10-candle lamps	. . 2·5 pf.,	about $\frac{3}{8}d.$	per hour.
16- "	. . 4·0 "	" $\frac{9}{16}d.$	"
32- "	. . 8·0 "	" $1\frac{1}{16}d.$	"
50- "	. . 12·5 "	" $1\frac{1}{2}d.$	"
100- "	. . 25 "	" $3d.$	"

In addition to this an installation fee of 6*s.* per lamp is charged, which includes one lamp.

Reductions in this scale are made for lamps burning a specified number of hours per annum, as

For 800 hours the reduction is . . .	5 per cent.
" 1000 " "	$7\frac{1}{2}$ "
" 1200 " "	10 "
" 2500 " "	20 "
" 3000 " "	25 "

A remission of 25 per cent. is granted to subscribers installing electro-motors, which have a special meter.

Meters are charged as follows:—

	£	s.	d.	
10- to 16-candle power	0	15	0	per annum.
25- " " "	1	0	0	"
50- " " "	1	10	0	"
100- " " "	2	0	0	"
600- " " "	10	0	0	"

A discount is allowed off this meter charge, varying with the number of hours the light is used in the year.

The cost of gas is about 4*s.* 9*d.* per 1,000 cubic feet, so the electric light is slightly the dearer illuminant.

The Aron meter, Fig. 73, is usually employed as the recorder of the electricity consumed. It consists of two pendulums, controlling two distinct clockwork gears. One oscillates at a regular speed, but the other has a permanent magnet, instead of a weight, and is variable in speed. The entire current passes through the solenoid, which is underneath the magnet pendulum; the difference in speed between the standard and variable clocks is given in direct ampere-hours by a counter.

gearing similar to the index of a gas-meter. An electro-magnet starts each pendulum when the current begins to flow, and immediately it ceases two detents come into operation and hold the pendulums stationary.

108 arc lamps of 15 amperes, enclosed in opal globes, placed 132 feet apart, and suspended 28 feet above the pavement, successfully illuminate the Unter den Linden. In the promenade, which occupies the central part of the thoroughfare, the lamps are suspended by chains attached each side to candelabra, which are of very artistic design.

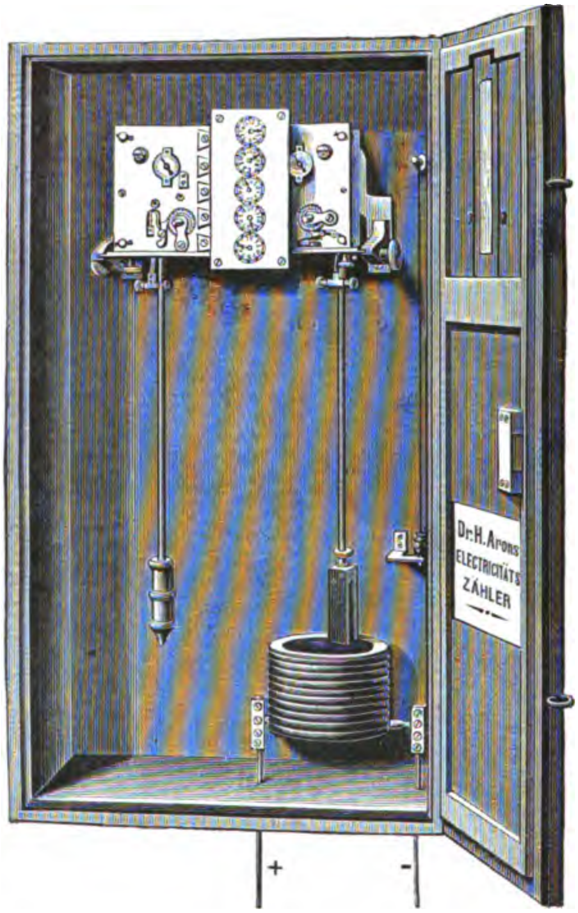


FIG. 73.—ARON METER.

ELBERFELD.

THREE-WIRE SYSTEM.

This installation was the first central station started in Germany on the Hopkinson three-wire system (Diagram C, Fig. 68), in which the three mains, instead of consisting, as is usual, of three simple cables, are combined in a triple concentric main. Although this arrangement has the objections that the separate leads are not so accessible, and in the event of damage all three would probably be affected, it has nevertheless proved very satisfactory, and has been adopted for networks even where the mains are frequently under water. In accordance with the plan considered best at the time the station was started, the dynamos were driven by belting, and further extensions were in view on the same plan; experience has now thoroughly proved the superiority of coupling machines directly to the steam engines, and the plant erected afterwards has been designed in this way. The total number of lamps supplied by the Elberfeld Station is about 9,000, and it is intended to increase the output by the erection of secondary batteries. The proportion of the number of lamps actually burning at any time to the total number installed is exceptionally high, being in the ratio of 4 to 5.

Fig. 74 shows a view of the dynamo room, and Figs. 75 and 76 the boiler-house. Each of the circuits is provided with an ammeter on both the positive and negative mains. The network of conductors is so arranged that it is unnecessary to regulate the voltage of the different branches, but only that at the centre of the network.

DARMSTADT.

THREE-WIRE SYSTEM.

The Darmstadt Central Station was the first in Germany in which the three-wire system was installed with separate cables. The palace and theatre had previously been worked on the two-wire system, and for these two places, where a large number of lamps were used, special arrangements were made. The Siemens and Halske dynamos, with inside field magnets, were at the time of erection the largest then working, and were coupled directly to Kuhn steam engines.

Figs. 77 and 78 show the engine room of this central station, and Fig. 79 a view of the boiler-house.

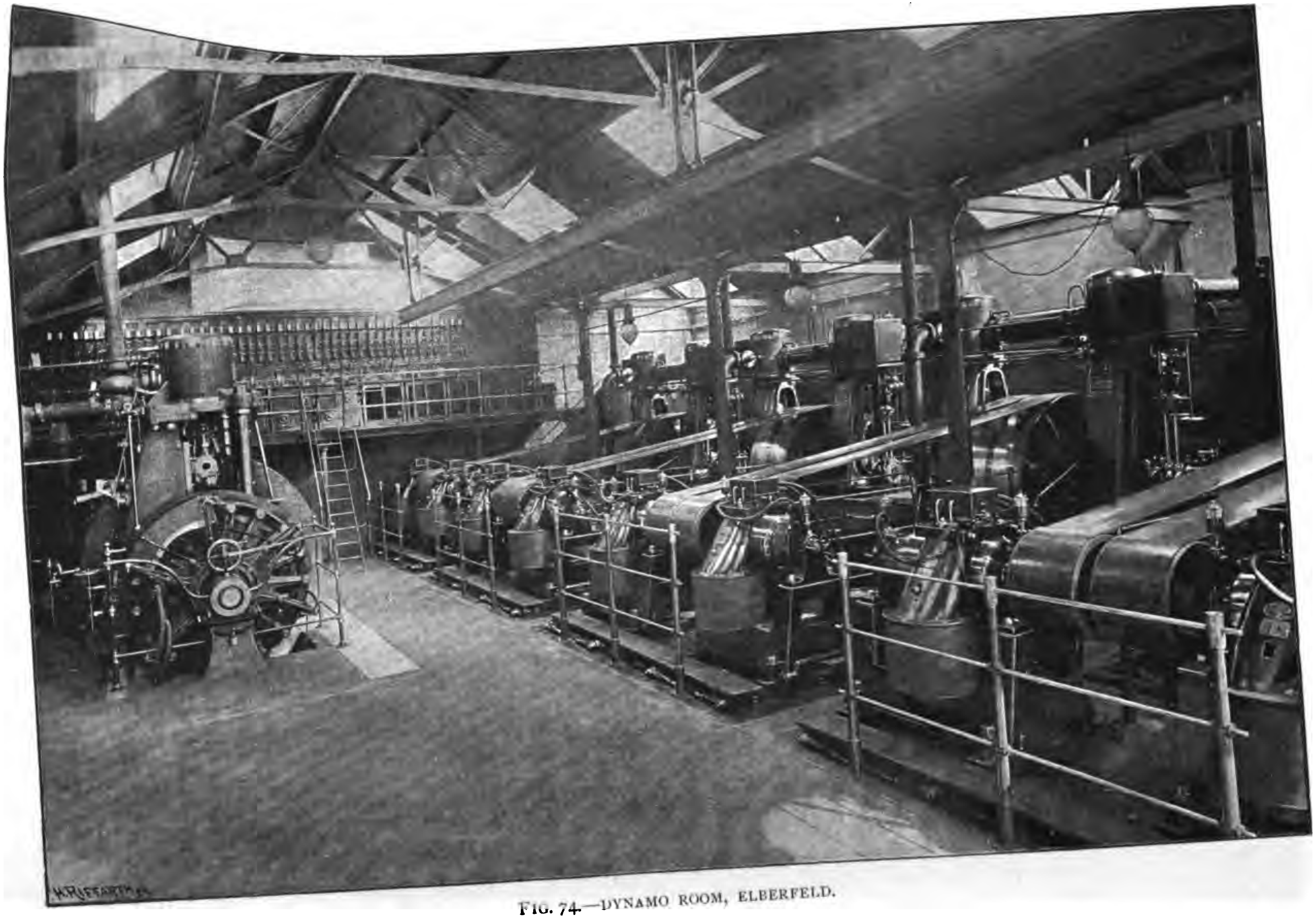


FIG. 74.—DYNAMO ROOM, ELBERFELD.

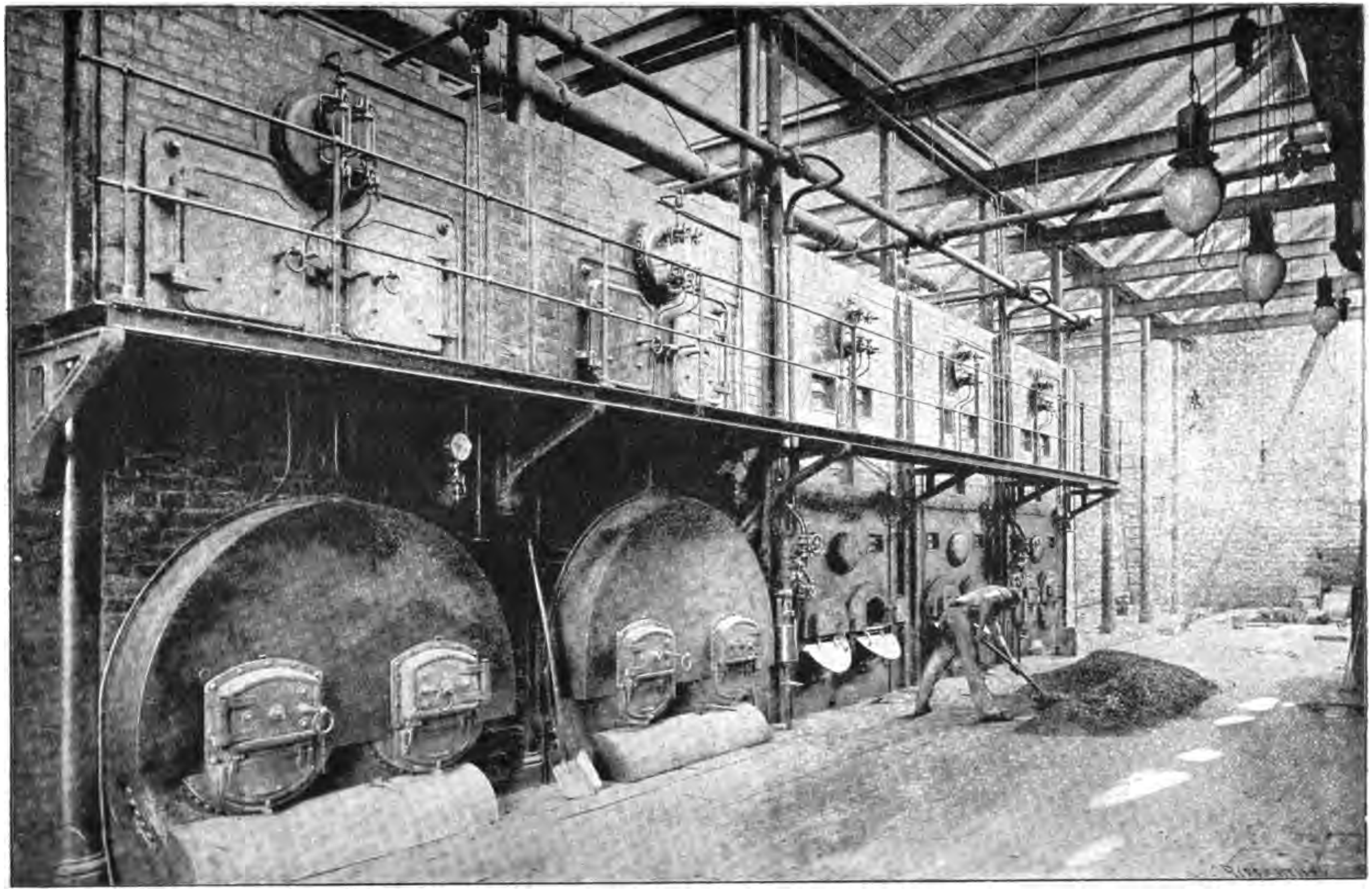


FIG. 75.—BOILER HOUSE, ELBERFELD.

FIG. 76.—BOILER HOUSE, ELBERFELD.

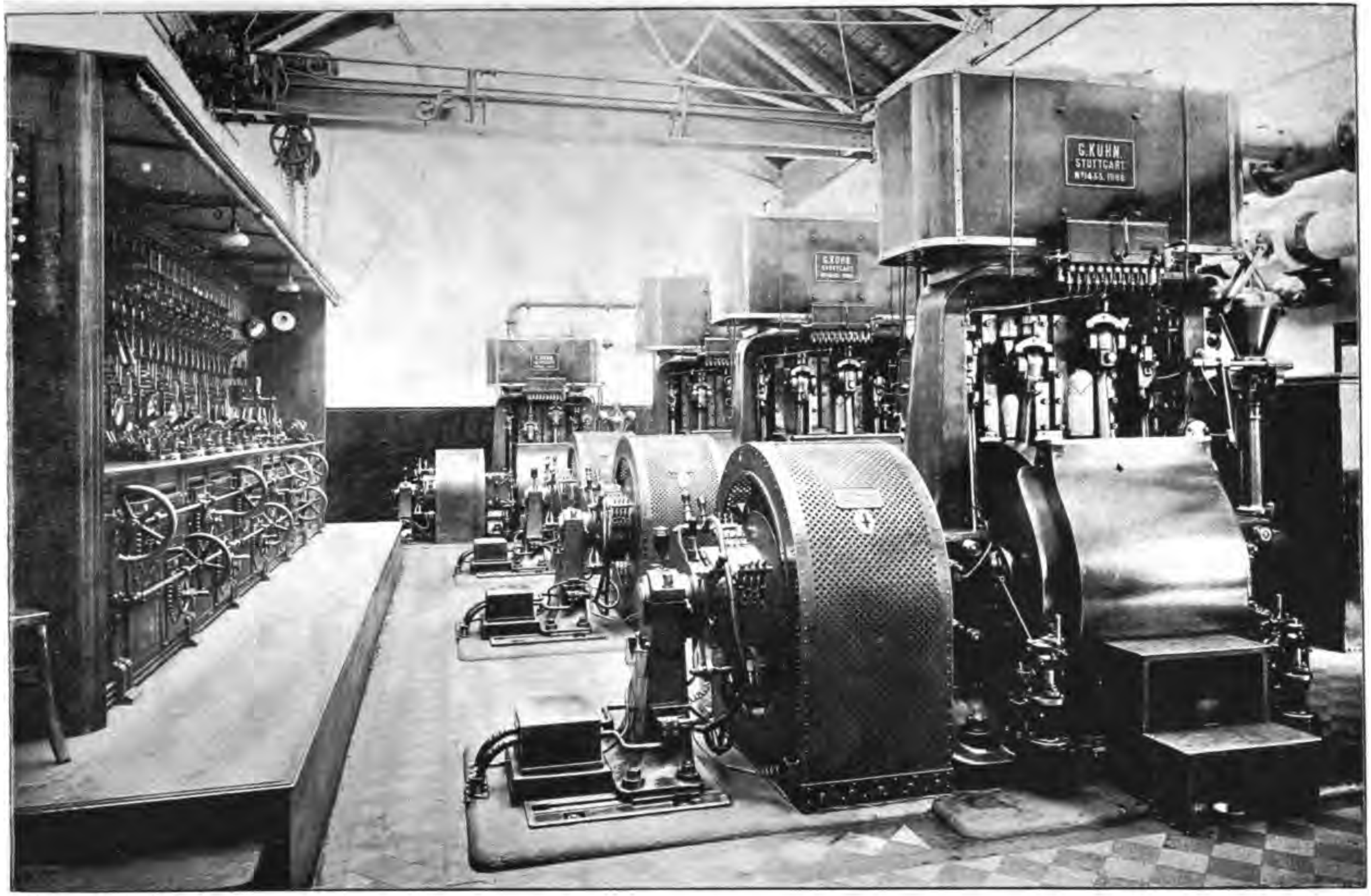


FIG. 77.—ENGINE ROOM, DARMSTADT.

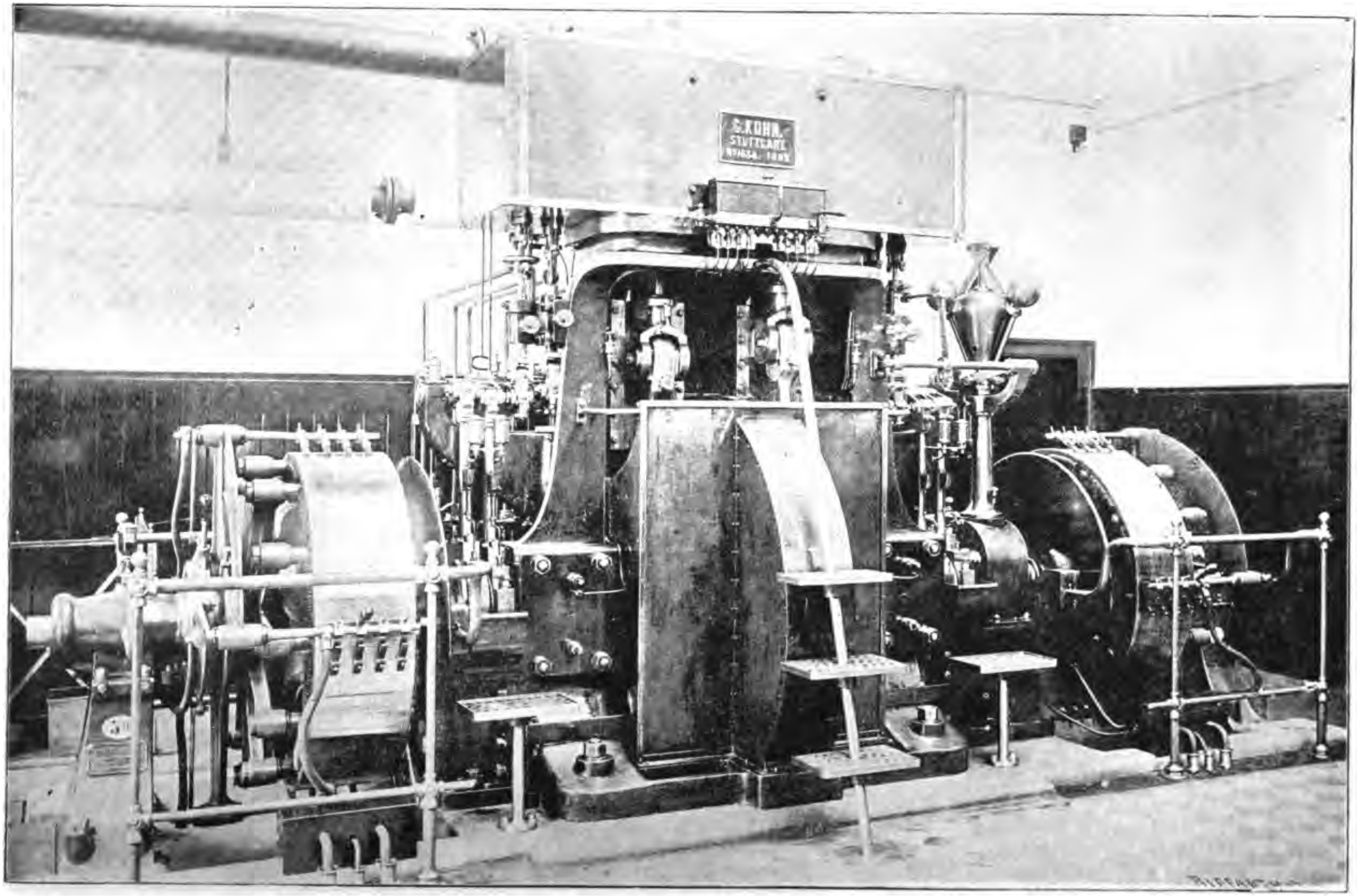


FIG. 78.—ENGINE ROOM, DARMSTADT.

FIG. 79.—BOILER HOUSE, DARMSTADT.

THE HAGUE.

The supply station at the Hague was started in the spring of 1889. A peculiarity of this installation is that the two main leads of the three-wire system are laid as a concentric lead cable, the balancing wire being a separate cable (Diagram E, Fig. 68). On account of the marshy soil, the greater part of the mains are laid in loam. Figs. 80 and 81 show the engine room, and Fig. 82 a view of the boiler house.

STETTIN.

This central station has at the boundary of the cable network a sub-station provided with accumulators, which are charged during the daytime. For the supply cables, the experiment was tried of laying bare wires in underground conduits of special construction. Figs. 83, 84, and 85 show the arrangement of engine room and dynamos, and Fig. 86 the boiler house.

BRESLAU.

Fig. 87 is taken from a photograph of the interior of the Breslau Station. The voltage of the supply mains is regulated by the secondary batteries (Diagram E, Fig. 68), each cable being supplied with an automatic switch, which keeps the voltage at the lamps constant at all loads. This arrangement has the advantage that it is not obligatory to have the cables so large as to give a practically constant potential over a considerable district, the difference being adjusted by means of the batteries.

SECTEUR DE LA PLACE CLICHY, PARIS.

This installation is an example of Siemens and Halske's five-wire system. (Diagram G, Fig. 68.) The steam engines of the Société Alsacienne are coupled

directly to 500 H.P. dynamos (with inside field magnets), producing an electromotive force of 500 volts. These machines are used in conjunction with four sets of secondary batteries, each set having an electromotive force of 110 volts. The arrangements are similar to this at Vienna and Trient. Fig. 88 shows a view of the engine room.

Paris is divided into sectors or districts, which are lighted on different systems. The most important are those using the Popp system of transmission of power by means of compressed air ; a description of these, and of another station in the Palais Royal, is given in "Engineering," Vol. XLVII.

The price charged to private consumers per kilowatt-hour varies at the different sectors ; for the public lighting it is 71 centimes per kilowatt-hour with arc lamps.

Sectors.	Francs.	Sectors.	Francs.
Edison	1·23	Marcel Deprez	1·1
Popp	1·26	Municipal, Halles Centrales	1·1
Place Clichy	1·36		

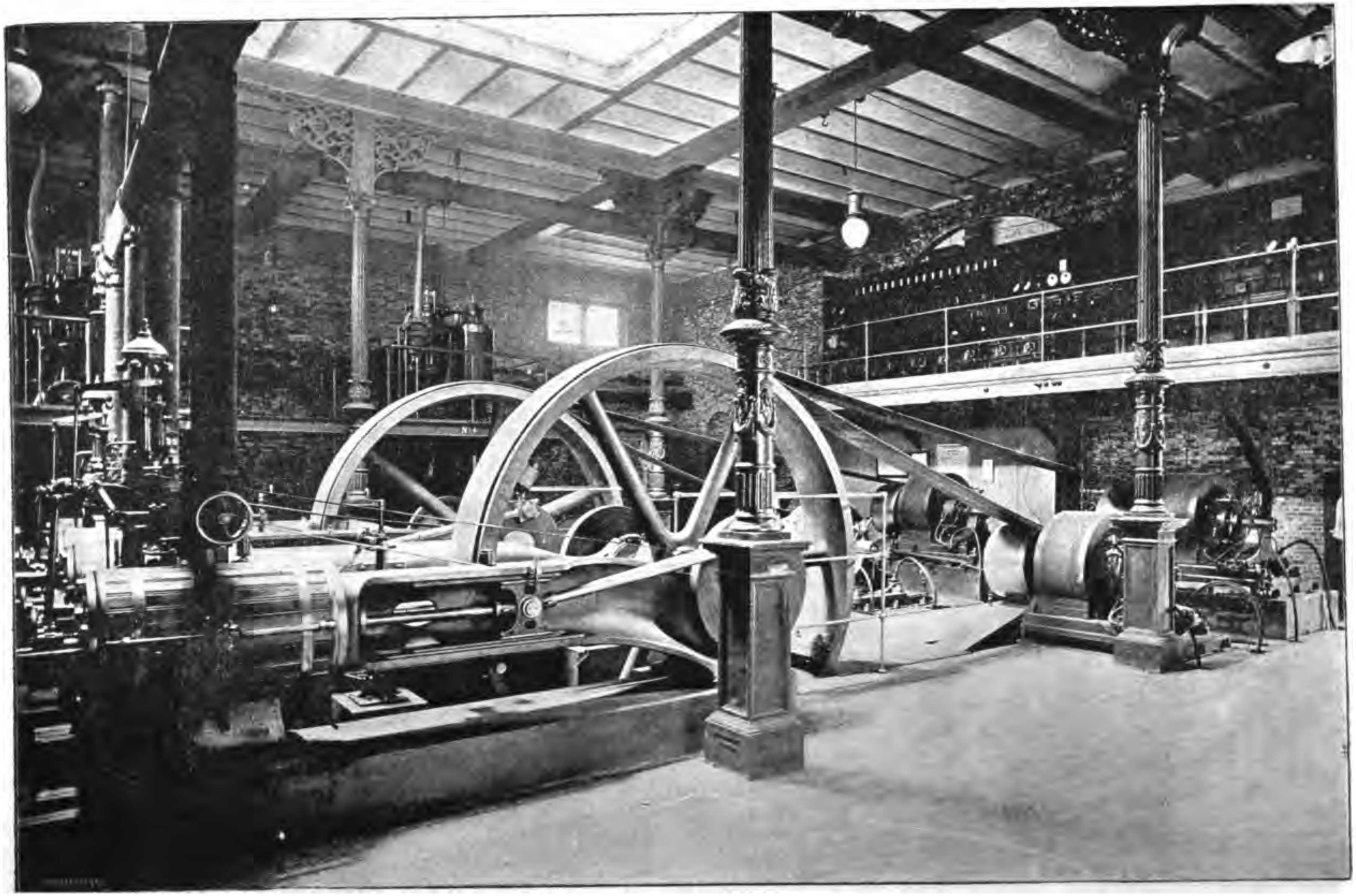


FIG. 80.—ENGINE ROOM, THE HAGUE.

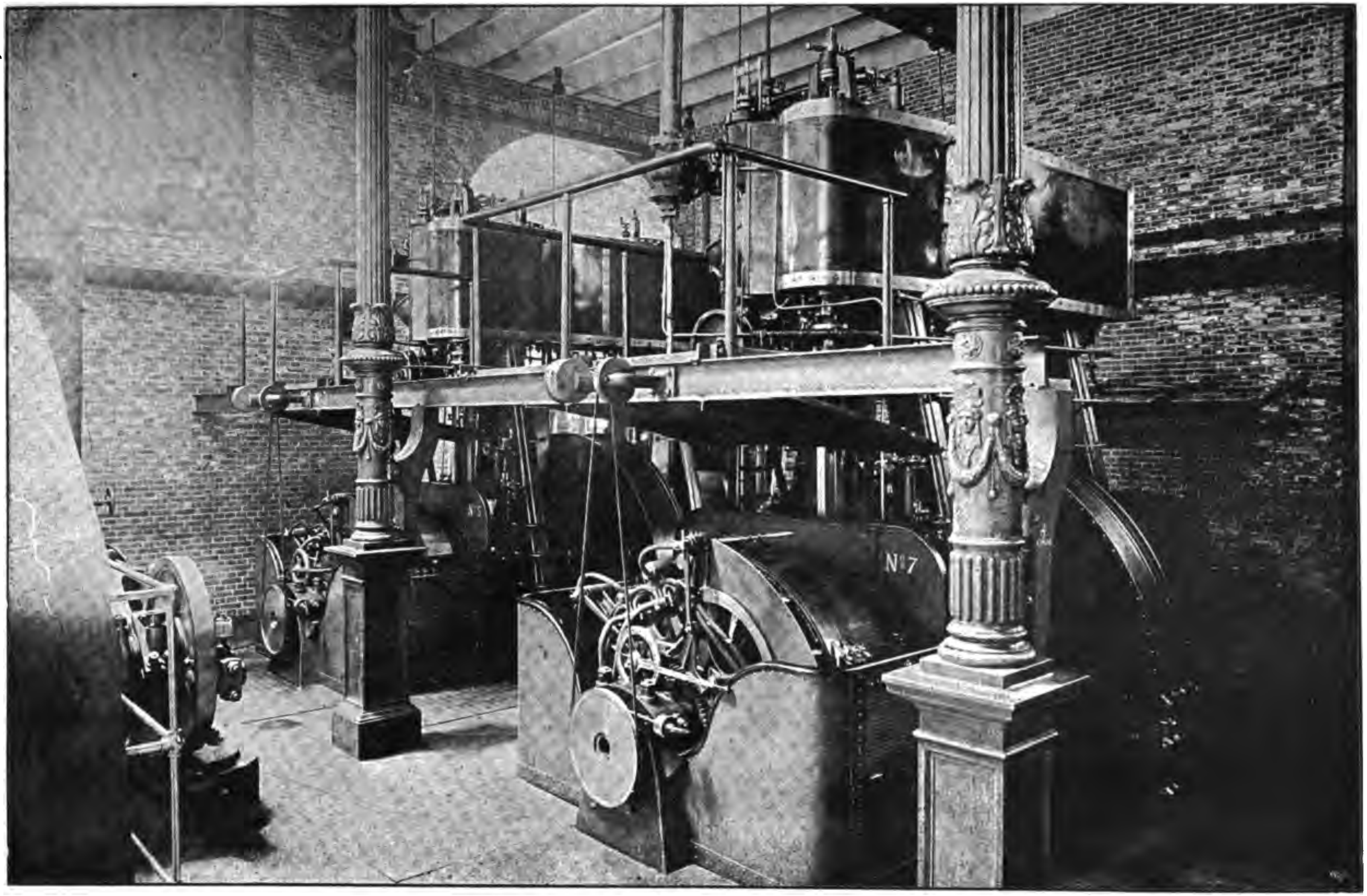


FIG. 81.—ENGINE ROOM, THE HAGUE.

S

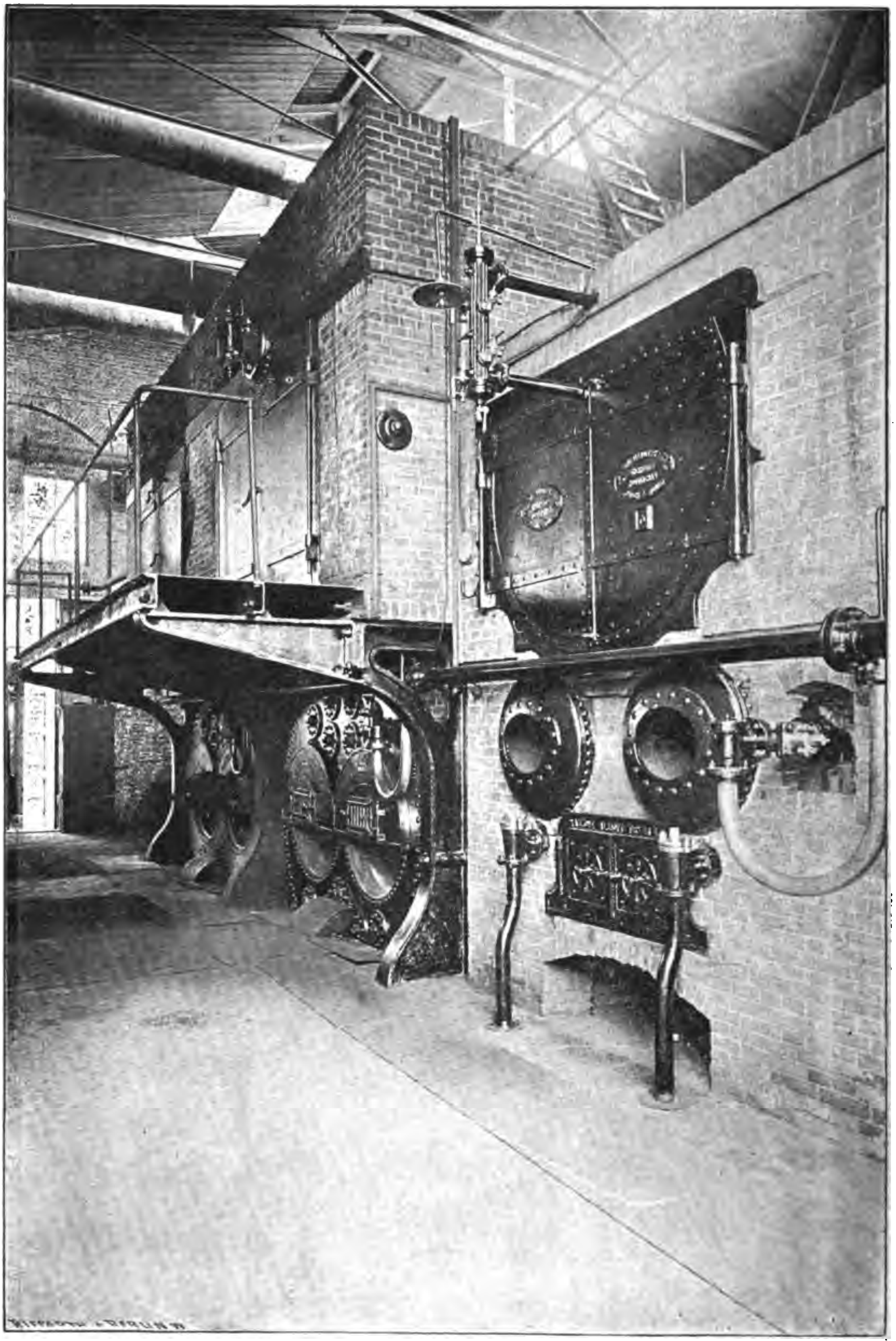


FIG. 82.—BOILER HOUSE, THE HAGUE.

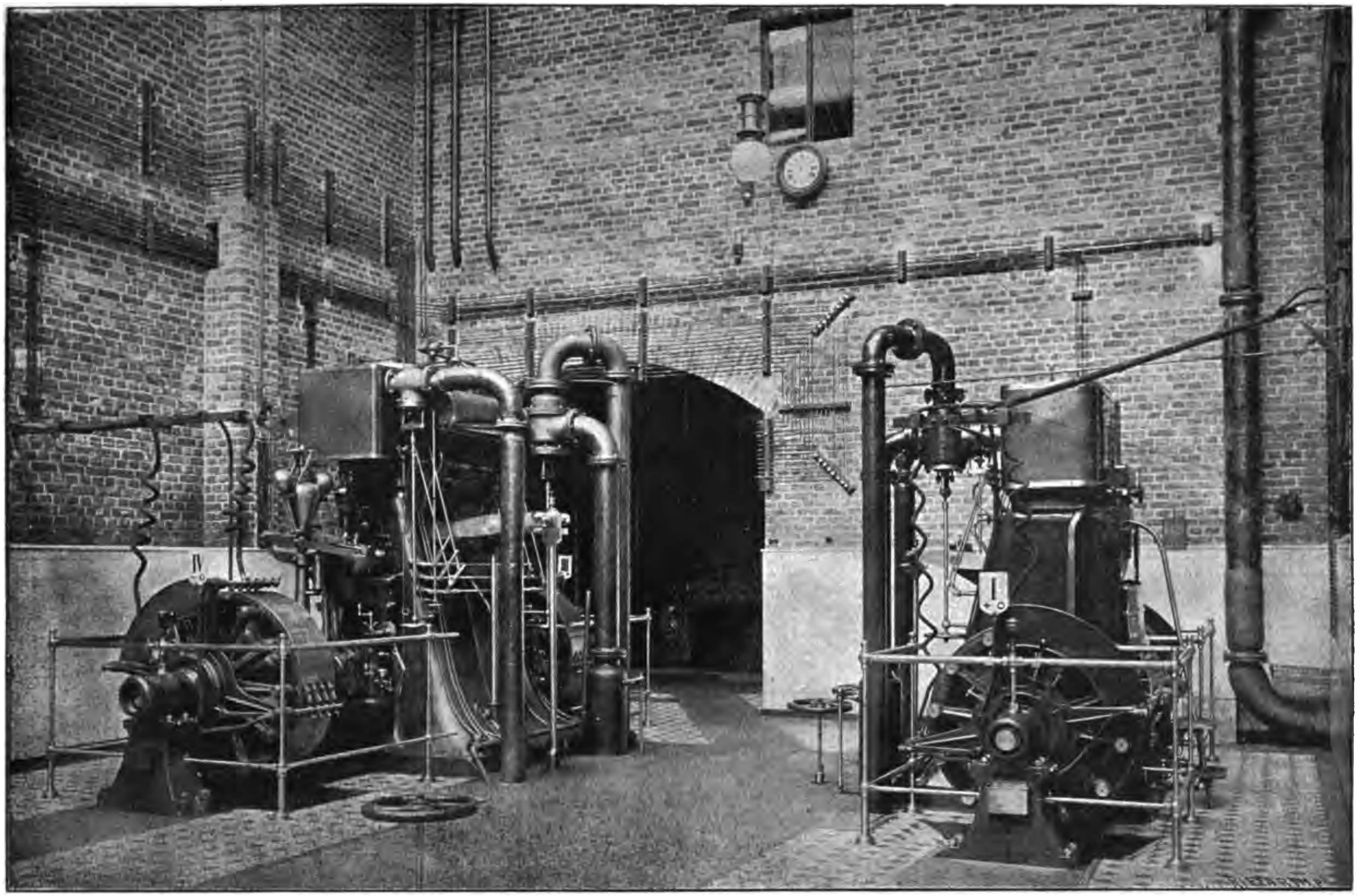


Fig. 83.—ENGINE ROOM, STETTIN.

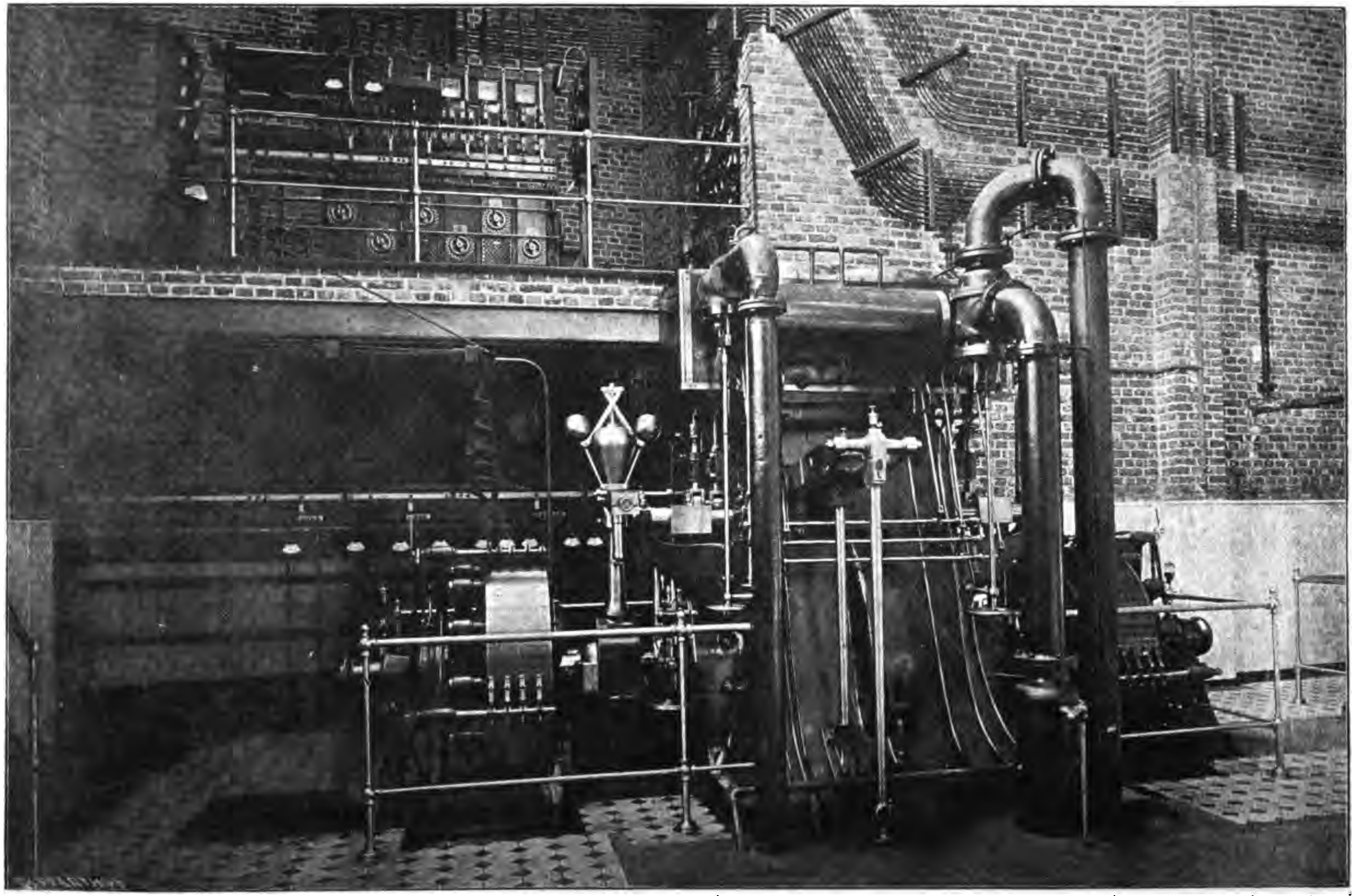


FIG. 84.—ENGINE ROOM, STETTIN.

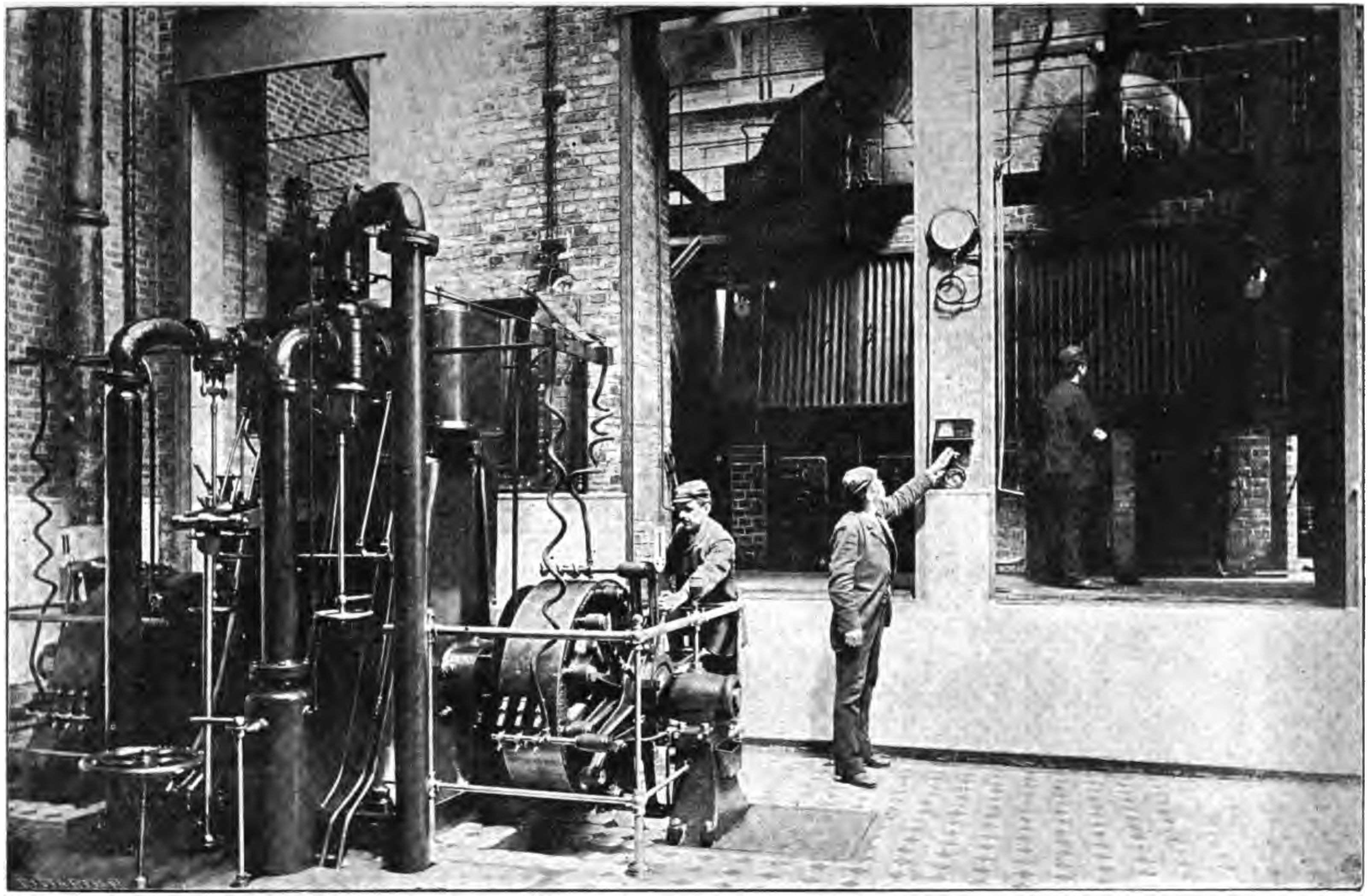


FIG. 85.—ENGINE ROOM, STETTIN.

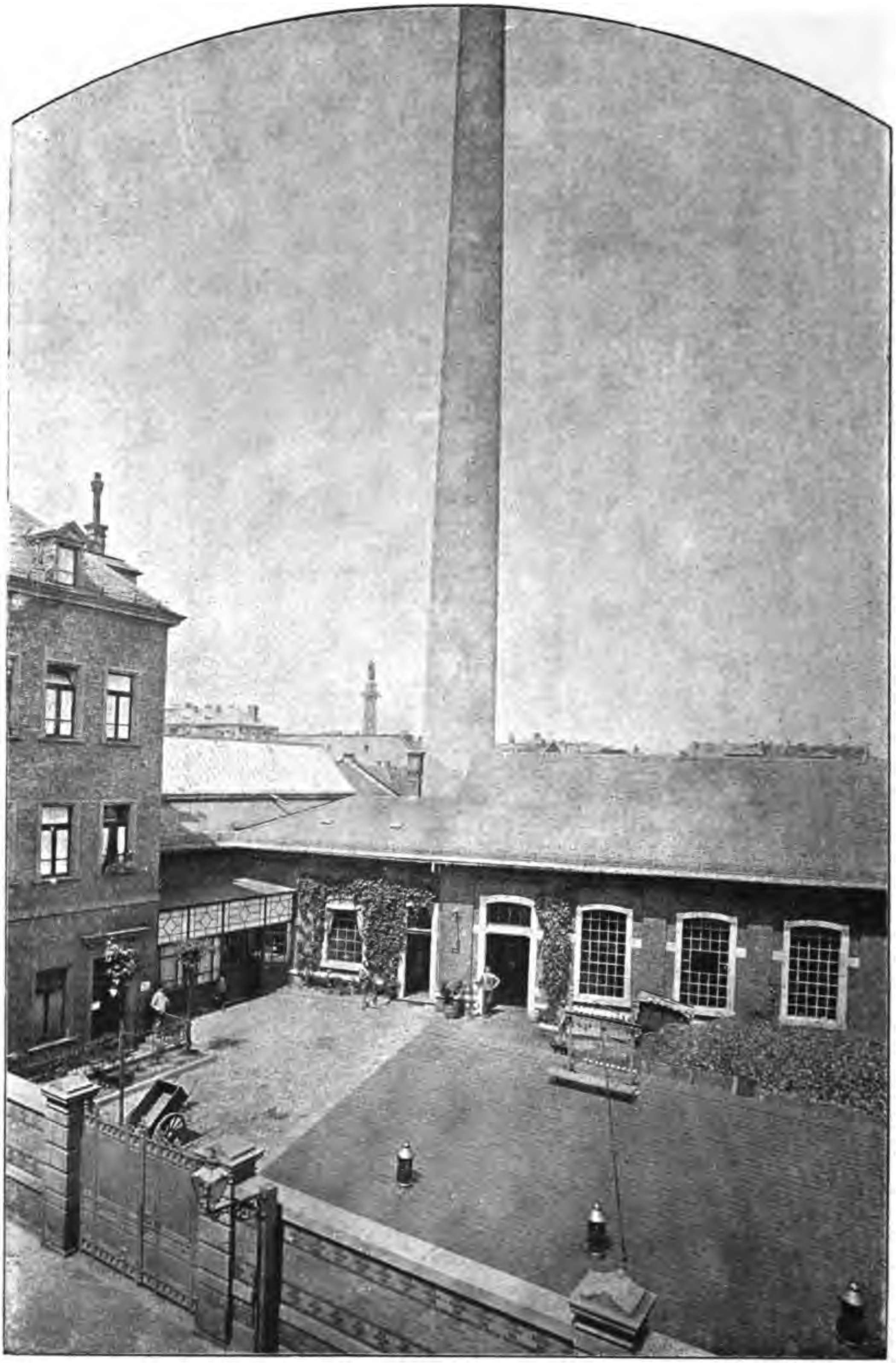
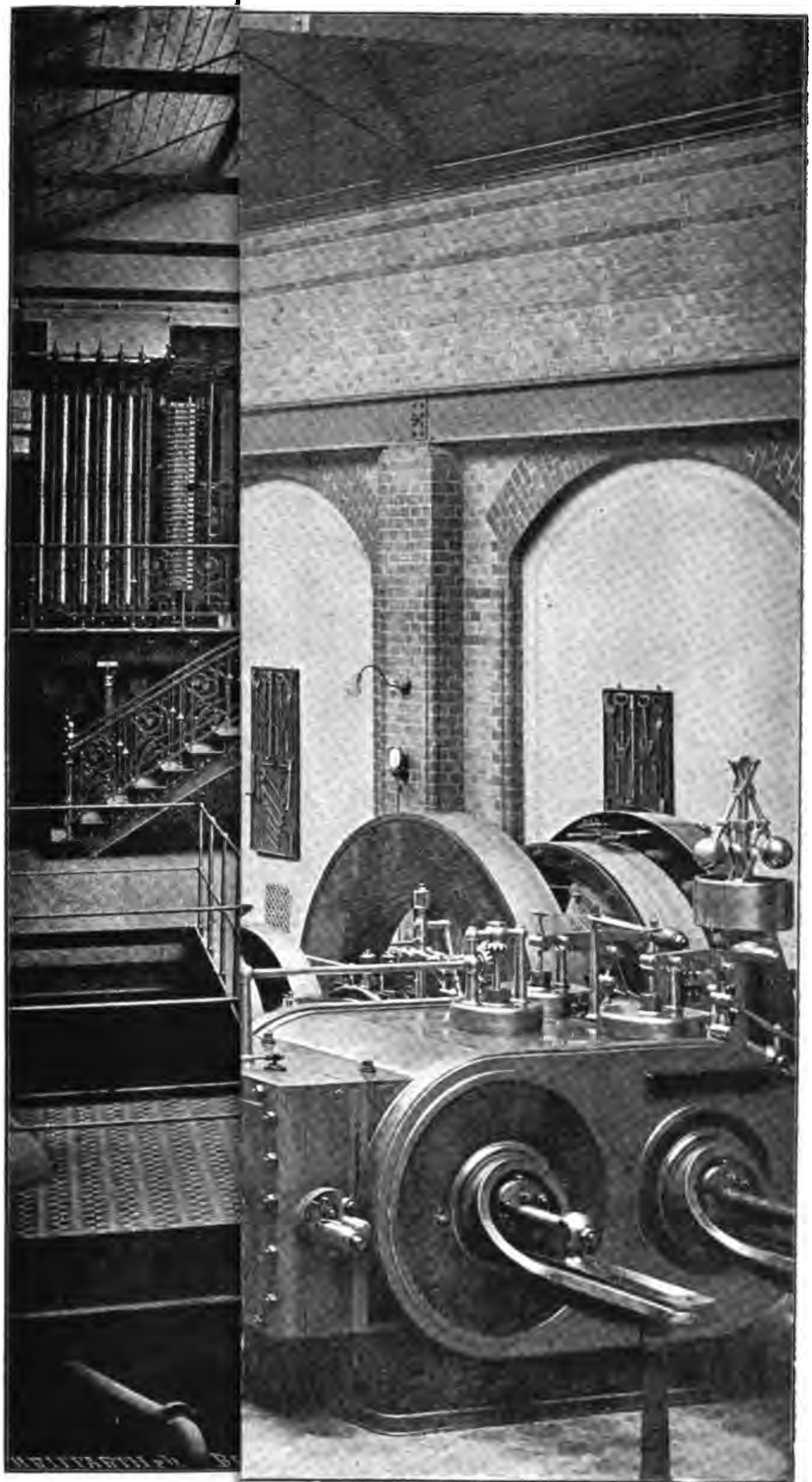


FIG. 86.—BOILER HOUSE, STETTIN.



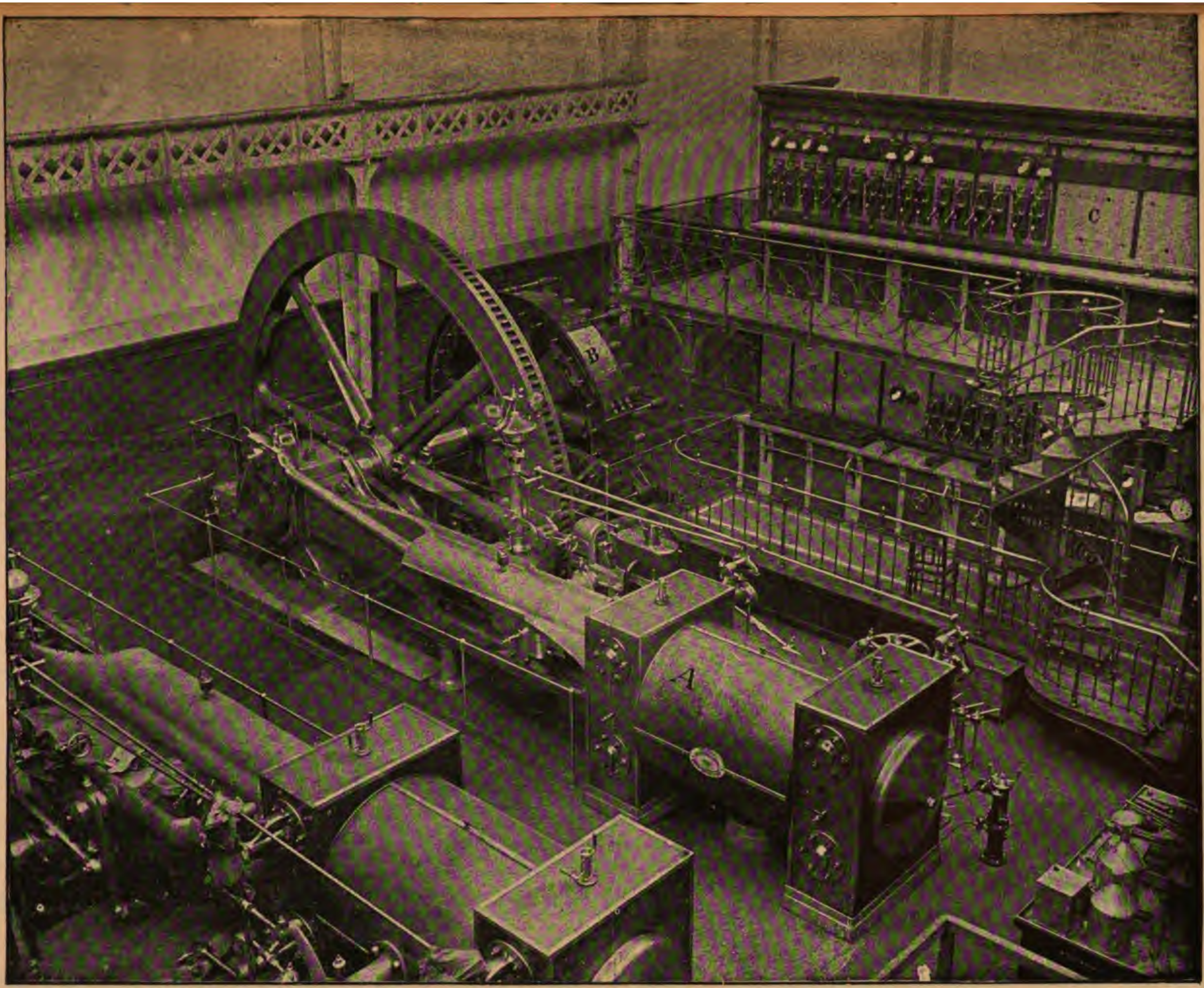


FIG. 88.—SECTEUR DE LA PLACE CLICHY, PARIS.

CONCENTRIC MAINS.

Messrs. Siemens and Halske have designed a complete system of lead-covered

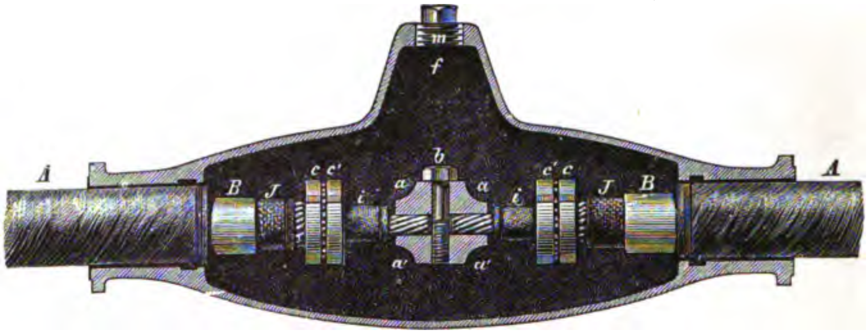


FIG. 89.

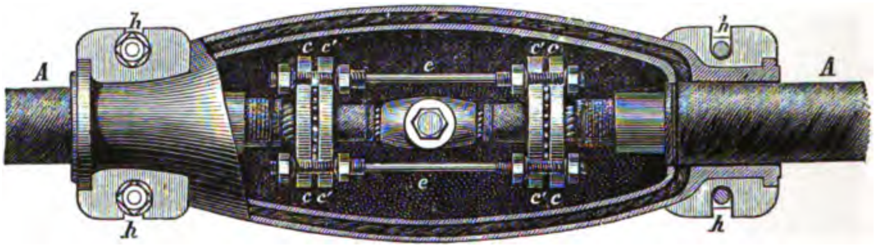


FIG. 90.

FIG. 91.

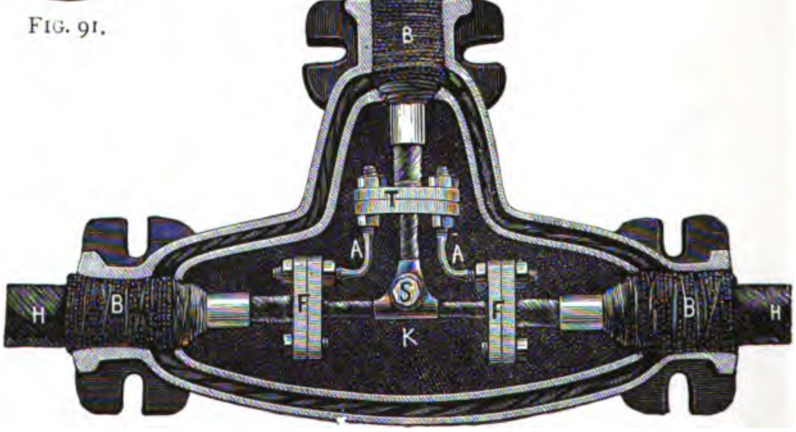
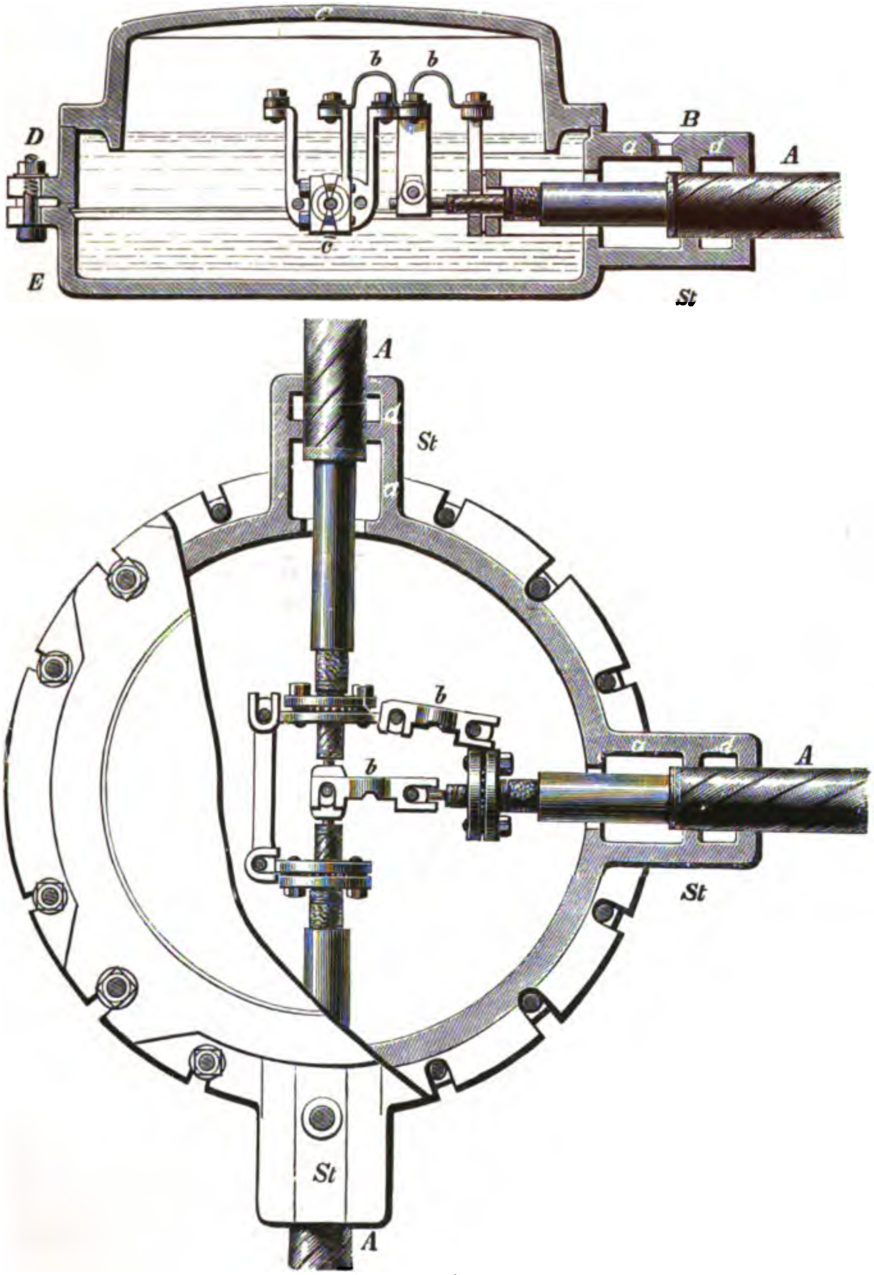


FIG. 92.

concentric mains, which have now been in practical use for a considerable period.

The method used to make connections is seen in the annexed illustrations. Figs. 89 and 90 show the jointing of two such cables: A is the outer tarred jute



FIGS. 93 & 94.

insulation, B the lead covering; the inner wires are shown connected by the clamps a a'; the wires of the outside stranded main are bent up and clamped between the flanges c c', shown separately in Fig. 91, these clamps being connected by the rods

e e; the junction box is afterwards filled up with insulating material through the screw hole, *m*, Fig. 89.

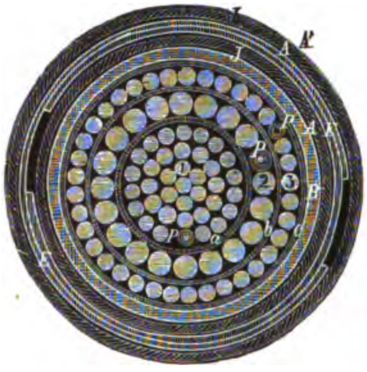


FIG. 95.

FIG. 96.

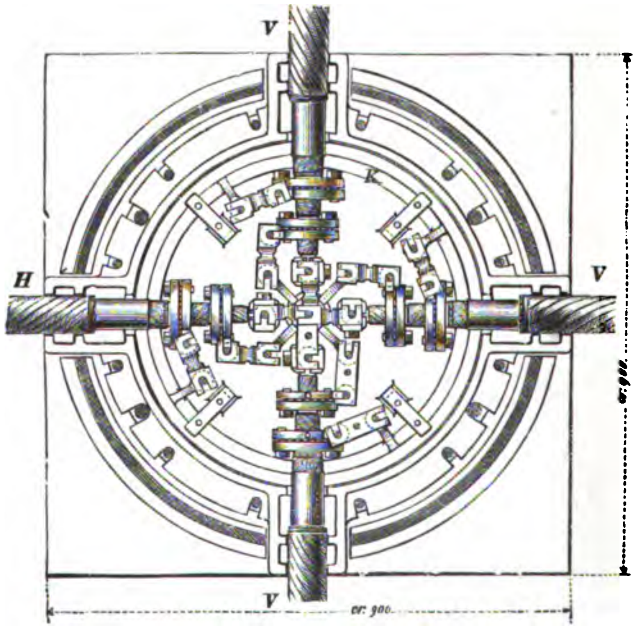


FIG. 97.

Fig. 92 illustrates a junction box for three mains on the same principle, and differs from the arrangement shown by Figs. 93 and 94, in that the latter are not filled

up, being made accessible, and having cut-outs with lead fuses, *b b*, inserted. Siemens and Halske also employ, for the three-wire system, a cable of three concentric mains. Fig. 95 shows such a cable full size, the total area of copper being 720 square millimetres (1·15 square inch). 1 and 2 are the main cables, and 3 the balancing main of smaller section; *a*, *b* and *c*, insulation; P, testing wires; B, lead covering; J, jute; and A, asphaltum insulation; E, iron armouring. Fig. 96 shows the method of joining these triple concentric mains. In Figs. 97 and 98 are the plan and section of a junction

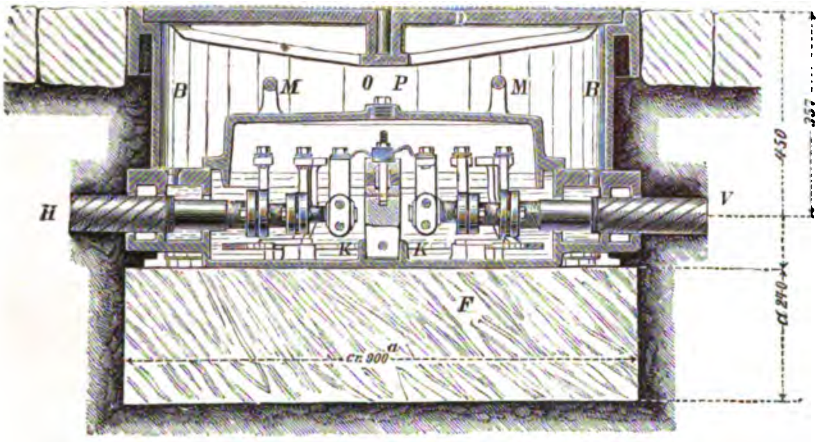


FIG. 98.

box for four cables; the two inner mains of each are connected as indicated through cut-outs with lead fuses, the external mains being joined by the metal ring, K. The dimensions are given in millimetres.

The use of concentric cables is becoming very general abroad, and many of the central stations which have been described employ this system. Experience at Berlin has shown that there is no danger of a break-down of insulation, even if currents of very high pressure are used; and in order to test this, a concentric cable was laid down at the recent Frankfort Exhibition and worked at a pressure of 10,000 volts.

Messrs. Felten and Guilleaume, Mulheim, also manufacture concentric cables, which are specially insulated with impregnated fibre or paper and covered with lead. This system is employed for the main cables of the new central stations at Aix-la-Chapelle, Christiania, and Amsterdam; at the latter, the pressure will be 2000 volts on the Ganz system.

MUNICIPAL REPORT ON THE ELECTRIC LIGHTING OF TRIENT (AUSTRIA).

CONTINUOUS CURRENT, FIVE-WIRE DISTRIBUTION, WATER POWER.

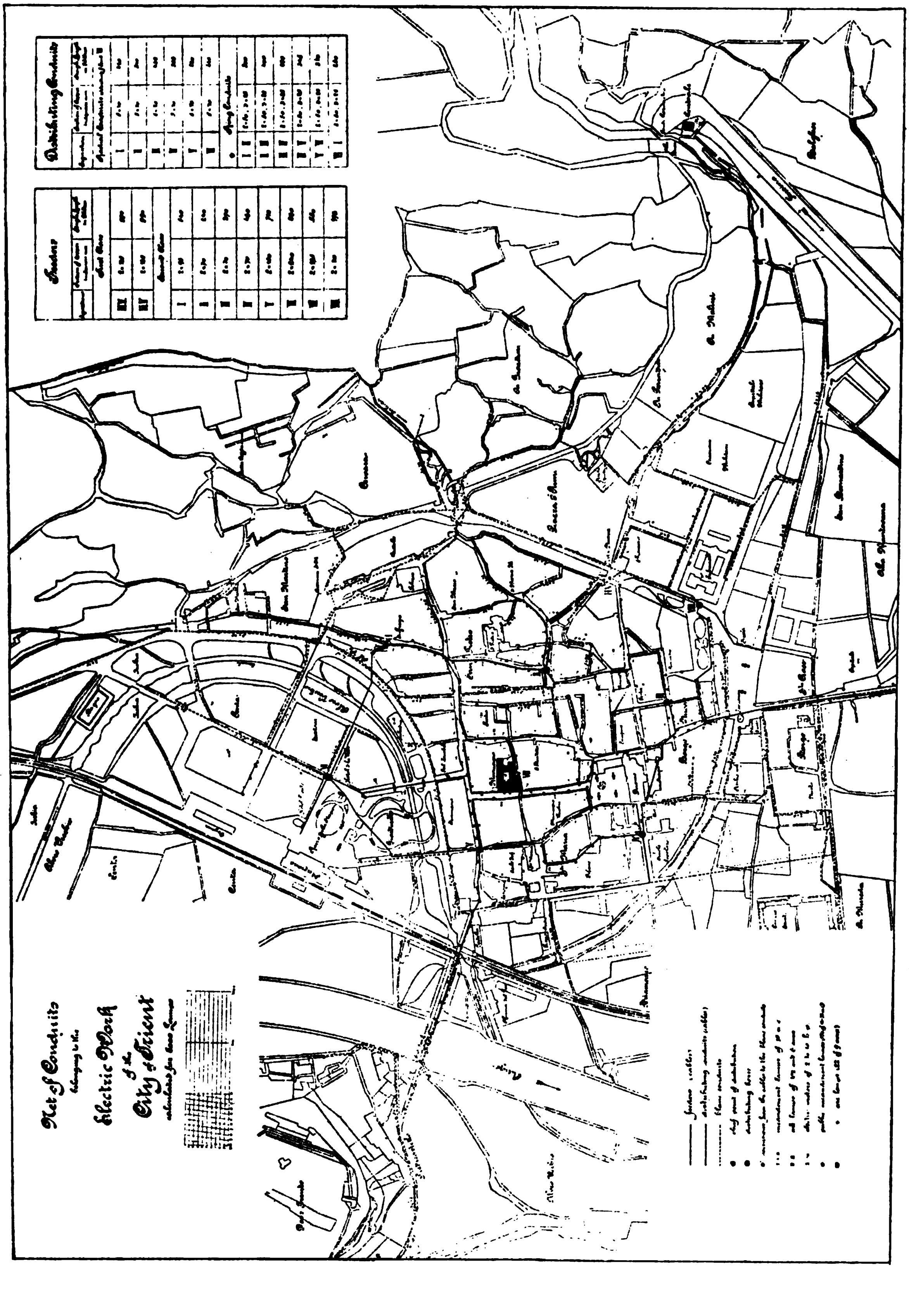
The motive power for this station, 600 H.P., is obtained from the river Fersina, from a flow of water of 154 gallons per second, with a fall of 282 ft., the water being brought by means of a tunnel conduit of 930 yds. and two cast-iron pipe conduits, 26 ins. inside diameter, 940 yds. long; the total distance between the point of water supply and the electrical machinery at Ponte Cornicchio being 1914 yards. The water power is used for driving six Girard horizontal turbines, each giving 140 brake horse-power at 250 revolutions per minute; these machines, provided with automatic regulators, are coupled direct to the same number of continuous-current dynamos of Siemens and Halske, each of 160 amperes at 500 volts output. There are also repairing shops, the machinery being worked by a turbine of 8 H.P., a three-ton travelling crane, storerooms, lodgings for the workmen, stores for installation materials; a telephone service between the high-level reservoir and the electrical station in the town, which is three-quarters of a mile from the generating station. At this station there are two "equalizing" dynamos, regulating the supply to the five-wire network; a set of accumulators serving as a reserve, and used during the time of maximum consumption and on Sundays and holidays.

The voltage of the five-wire mains is 440, giving to the incandescent lamps 110 volts, to the arcs 55, and to the electromotors from 110 to 440 according to their power The system is provided with radial feeders and ring circuits, with ten distributing boxes. In the inner part of the town, lead cables of Siemens and Halske, doubly iron-armoured, are used, and for the house connections lead cables laid in gypsum; in the suburbs the mains are not protected. The network, calculated for 800 H.P. electrical energy, is laid in all the streets of the town and suburbs at an average distance of 984 yds. from the centre, the greatest distance of a building supplied being 1530 yds. from the centre of the town and 2850 yds. from the generating station at Ponte Cornicchio. Plate XX. shows a plan of the town of Trient, with the network of mains.

The plant was erected by the municipal water works department, who supplied the sluices, water tunnel, the high-level reservoir, the engine-house, buildings, fittings for lamps, etc. Siemens and Halske, Vienna, furnished the electrical machines and switch-boards; the Ateliers de Construction Mécanique, Vevey, the iron water conduits, the turbines, regulators and travelling crane.

TARIFF CHARGED.

The current is charged for by the year, no meters being used, and is available for lighting throughout the 24 hours and for power 20 hours per day except on Sundays and holidays. For public lighting £1000 per annum is paid, being the same as formerly


Net of Conduits
Electric Work
City of Trient

paid for the gas and petroleum lamps. For private lighting 1*s.* per annum is charged for each candle-power for incandescent lamps of 5 to 35 candle-power; 13*s.* 9*d.* per annum per ampere for arc lamps. For electromotors, 40*s.* per H.P. measured at the turbines, or about 60*s.* per brake H.P. of the motor. The consumers pay for installing, repairs and renewals. The sale of incandescent lamps and coals, the carrying out of new installations and repairs are undertaken by the municipality; incandescent lamps of 5 to 35 candle-power are sold to citizens at 4*s.* each, to workmen at 2*s.* each. Electromotors can be ordered from any firm by the users, provided the machines comply with the necessary conditions.

The total expenses of the plant, when the supply was started in June, 1890, amounted to £64,700. The supply has been—for public lighting 22 arc lamps, 9 amperes, burning until midnight, and 560 incandescent lamps burning every night; for private purposes—30 arc lamps, 6 amperes, 6000 incandescent lamps of from 5 to 35 candle-power, average 12 candle-power; 30 electromotors from $\frac{1}{16}$ to 50 H.P., with a total of 200 H.P. measured at the turbines.

The town of Trient has 22,000 inhabitants, including a military force of 1900 soldiers. The public lighting with incandescent lamps is three times as strong as the 230 gas and petroleum burners formerly employed, which also cost about £1000 per annum. The gas-works were started in 1859 and in 1890 supplied 190 public and about 1900 private burners; the gas-works now supply about 100 private lights and about 20 gas stoves, with a consumption of about 2800 cubic feet of gas per day.

FINANCIAL RESULTS, 1891.

(*a.*) Receipts :—

	£.	£.
For public lighting	1000	
„ private „ 70,000 candle-power at 1*s.*	3500	
„ 30 arc lamps about	150	
„ 200 h.p. motors at 40*s.*	400	
„ profit on lamps, coals, &c., about	600	
„ „ „ installations, about	200	
		5850

(*b.*) Expenses :—

	£.	
Interest on plant, £64,700 at $4\frac{1}{2}$ per cent.	2900	
Technical and general management and workmen's wages	840	
Expenses of maintenance, &c.	1110	
		4850
Profit balance		£1000

Several new installations are being put up and many more contemplated, so that it may be expected that the private consumption will soon rise to 100,000 candle-power

and 300 H.P. for electromotors; private consumers can be supplied up to 130,000 candle-power, and with motive power up to 500 H.P., with the plant that is now erected. The installation may be considered a success for several reasons. Each effective H.P. at the turbines gives 150 candle-power of light (incandescent) and about 60 per cent. useful effect at the motors. The prices of supply are very low, which is an advantage to the small retail trader, consequently the electric light has very speedily come into use for public establishments and private dwellings, and has replaced the unwholesome gas and petroleum lighting; it is also introduced already into nearly 300 workmen's dwellings. The undertaking may also be considered successful financially, as the public lighting is three times as powerful and cheaper than the former gas and petroleum lighting, and these illuminants do not offer the many advantages of the electric light.

ELECTRIC LIGHTING AT TRIESTE, GABLONZ, AND ARCO.

By Kremenezky-Mayer & Co., Vienna.

TRIESTE CENTRAL STATION.

The building of the Trieste harbour, and the great increase of traffic which resulted, caused the Trieste Chamber of Commerce to introduce a system of electric lighting.

For the motive power three vertical compound engines of E. Skoda, Pilsen, are employed, the diameter of the high-pressure cylinders being 16 inches, that of the low-pressure 24 inches, with a stroke of 20 inches, and a maximum working pressure of 100 lbs. on the square inch, giving 150 H.P. each at 150 revolutions per minute; two surface condensers are used, and steam is obtained from Cornish boilers, which also work the pumps for the hydraulic power supply. Each of the three steam engines drives two dynamos, which give an output of 45,000 watts at 300 volts; two of the steam engines will therefore work four machines (180,000 watts), whilst the third engine remains in reserve.

The dynamos employed are of the Manchester type,* having drum armatures, with wrought-iron magnets, cast-iron pole pieces, and at 500 revolutions give an efficiency of about 96 per cent. The mains are all run overhead on the three-wire system, using 150-volt glow lamps; arc lamps are put six in series on to the 300-volt mains, so arranged that alternate lamps are in different circuits, and are mounted on poles 33 feet high.

This station has been supplying about 100 arc lamps and about 3000 glow lamps in various buildings, including the Barcola Railway Station.

GABLONZ CENTRAL STATION.

THREE-WIRE SYSTEM WITH SECONDARY BATTERIES.

The inferior light provided by the gas company of the town of Gablonz, a great industrial centre, and the inadequate supply, resulted in the establishment of an electric light station. At first the gas company, who contemplated a similar project, and fearing the depreciation of their business, placed as many difficulties in the way as possible.

The station was erected at the establishment of the firm of Hoffmann, a mile

* This type of dynamo was designed by Dr. Edward Hopkinson, and is supplied by Mather and Platt.

and a quarter from the town, the turbines employed having a total power of 250 H.P. and two dynamos being used of 30,000 watts output. These machines work in parallel, and charge two sets of Tudor accumulators in the centre of the town, the distribution being on the three-wire system. The cells, having a capacity of 630 ampere-hours, can supply 750 glow lamps, the normal consumption, without the dynamos; the present undertaking could therefore supply 1500 16-candle power lamps, equal to about 2500 installed. The utilization of power for both the workshops of Messrs. Hoffmann and for electric lighting is especially advantageous, as, during the time when there is the greatest demand for the former, the supply for lighting is very small and can be maintained by the accumulators. The cables are all laid underground; two lead-encased mains of ·6 inch diameter connect the accumulators to the station, the cells supplying a three-wire system of lead cables laid underground in wooden conduits. As the gas company still supplies the street lighting, the electric light is at present only employed in hotels, dwelling-houses, etc., the cost being lower than gas.

The installation, including the accumulator station, will have cost, after completion, not more than £10,000. Particulars of the cost of working cannot be given, but the expense for maintenance is extremely small, as the accumulator makers have a ten-years' guarantee for maintenance at a cost of £120 per annum, to include repairs to the switches and cables.

ARCO CENTRAL STATION.

This station has been erected at the expense of the municipality. The power is obtained from the Fitta canal at the mill of Messrs. Tosi, where a fall of 13 feet, with a quantity of water of 550 gallons per second, is available, and drives three Girard turbines, made by the Austrian Alpine Montangesellschaft, each of 115 H.P., working six continuous-current dynamos of 30,000 watts; one turbine and its two dynamos are kept in reserve. The station is able to supply 2500 glow lamps. The cables are of bare copper wire, run overhead. The lighting of the public streets, by 160 glow lamps of 32 candle-power, is so arranged that, in the event of their failing, another circuit is connected automatically which lights arc lamps in the more important places. It is intended to erect an accumulator battery as a reserve. The following consumption has been guaranteed by the town:—(1) About 4300 burning hours per annum for street lamps, from sunset to sunrise; (2) For the 2000 glow lamps in private buildings, from October to the end of April, about 1500 hours per annum, from sunset to midnight; (3) About 300 lamps burn the whole year for 750 hours longer than the rest, from sunset to 10 o'clock.

Arco is a health resort rapidly extending in favour, in the immediate neighbourhood of the Gardasee, and vies with the sister town of Riva in utilizing the products of modern advancement. The electric light is appreciated by visitors, who find it an improvement over the former plan of lighting by means of oil lamps.

ELECTRICAL CENTRAL STATIONS.

DISTRIBUTION WITH SECONDARY BATTERIES IN RESERVE.

BY O. L. KUMMER & CO., DRESDEN.

In projects for the establishment of central stations for the distribution of light and power, there has to be considered on the one hand the many advantages of accumulators, on the other the uncertainty of their life and their great cost; for these reasons it may be advisable to use them as a reserve only, and for supply during the night. The plan adopted by Kummer & Co. to meet the rise of potential during charging of nearly 40 per cent. is to use a separate dynamo for this purpose, whilst the voltage of the charging dynamo remains the same. The following figures explain the method used. Fig. 99 shows the arrangement for charging during the daytime; for

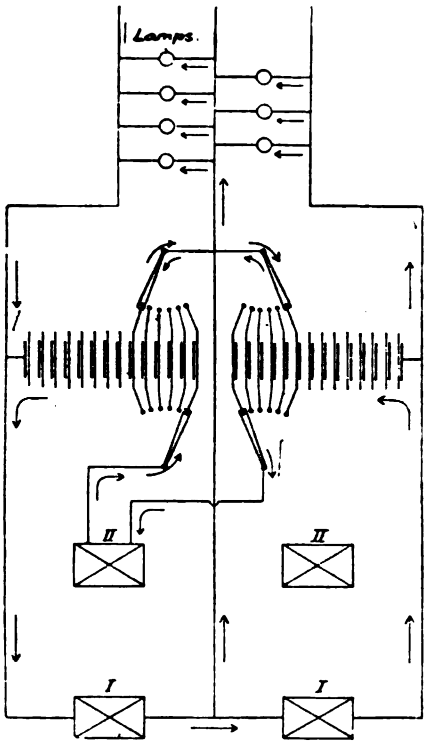


FIG. 99.

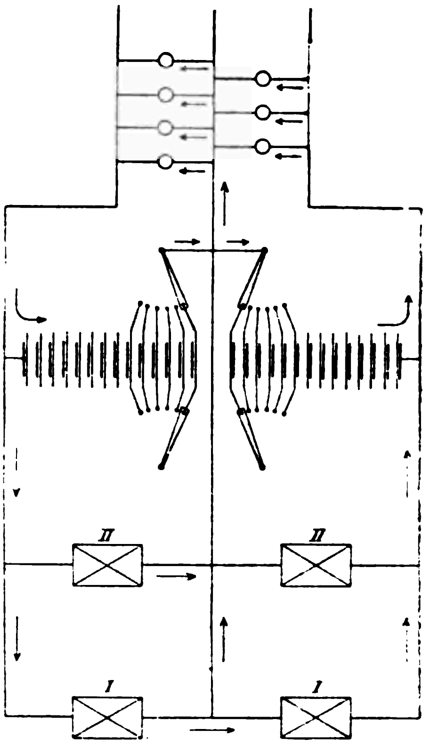


FIG. 100.

meeting the rise of potential of the cells the dynamos II, II, are used; these are put in parallel with the other machines I, I, and the accumulators during the time of large demand, as illustrated in Fig. 100. This design, whilst not increasing the cost of plant, renders the working very economical, and increases the durability of the accumulators, and prevents waste of power by overcharging.

THE LIGHTING AND DISTRIBUTION OF POWER AT THE ESSLINGEN WORKS.

ON THE MULTIPLE-WIRE SYSTEM WITH EQUALIZING DYNAMO.

The Esslingen Engineering Works have erected several central stations on the five-wire system, and a few small stations on the three-wire system; the former plan is used for the lighting of the Esslingen works. Evidently, for stations distributing electricity to a short distance, only two or three wires are required, but for the economical transmission of electrical energy to greater distances a five-wire method may be advantageously employed, the high tension then used conducing to saving of copper, and consequently reducing the interest by lowering the capital required. The multiple-wire system has all the advantages of parallel distribution, in that the lamps are completely independent of one another; at the same time, the economy is equal to that of the transformer method. Working in series has been attempted, but, although giving great economy in mains it does not allow independence in the circuits. Fig. 101 shows the arrangement of an ordinary three-wire system,

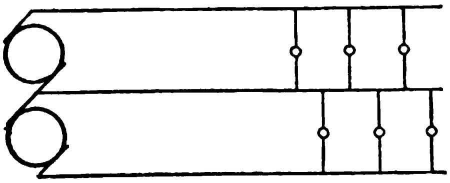


FIG. 101.

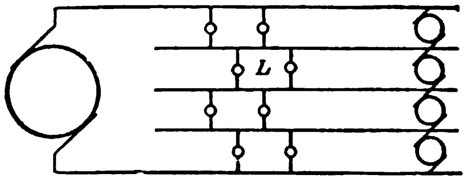


FIG. 102.

with two dynamos supplying current to the leads according to the varying demand. As in many cases it would be impracticable to use three or four dynamos with a four or five-wire system, an equalizing dynamo is employed in the manner represented in Fig. 102. The main generating dynamo may be outside the supply district, the equalizing dynamo being at the second station to distribute current to the mains. If four dynamos are connected to the network and supplied with current from the principal generator, they will work as motors, and, being exactly alike, generate the same counter electro-motive force, which, however, will vary in each machine according to the number of lamps burning, so that the electro-motive force between each pair of mains is automatically kept constant. To such an arrangement as this there are various objections, more especially with regard to the regulation of the field magnet excitation and the difficulty of rocking the brushes to prevent sparking on the commutator; these difficulties are completely met by dispensing with the separate dynamos, and using a single machine with several windings on the armature. If a machine is run as a motor, it is necessary to shift the brushes in the opposite direction, and when using separate machines the excitation has to be varied; but if a machine is used having several windings on the armature with one field magnet, the armature reactions are kept approximately constant as the currents in the

several windings practically balance one another. As the magnetization of the field magnets is also constant, there is consequently no need to shift the brushes to avoid sparking; the windings are all similar, and work in the same magnetic field, so the voltage of each must be the same. In a well-built machine the losses due to resistance are very small. Each winding has its own commutator, the brushes of which are connected to one pair of mains. With a difference of 20 per cent. in the main current, the potential at the lamps does not vary more than 1·5 to 2 per cent., and as this is unnoticeable in the lighting, further regulation is unnecessary. In cases where land and buildings are valuable, the primary station may be situated outside the town without the cost of leads to the town being excessive; the management of such a station is extremely simple. The equalizing machine, with one in reserve if considered necessary, is placed at the secondary station with the usual safety appliances; ammeters and voltmeters are not generally required, as the machine distributes automatically. The mains for house and street lighting as well as for motors can be connected to any pair of the five wires, according to the voltage required, as shown diagramatically in Fig. 103. This plan is especially suitable for motors, as the working electromotive force can be arranged to suit their design; for instance, when required for street traction, a reasonably high voltage may be employed, to reduce the difficulties of taking up the current by means of rubbing contacts. A multiple-wire system with an equalizing dynamo has very few objections, and offers greater advantages than an ordinary direct distribution.

After comparison with other methods, the Esslingen Maschinenfabrik decided to adopt a five-wire system (480 volts) in their own works at Esslingen.

In the diagram, Fig. 103, A is a compound machine, giving, at a speed of 670 revolutions, 480 volts, and a current of 62·5 amperes, or 30,000 watts. This dynamo supplies current through mains, H, ·28 inch thick, supported on oil insulators, to the equalizing dynamo, B, at a distance of 440 yards. In the works there are motors:—C, 10 H.P., 480 volts, supplied direct from the primary mains; D, 2 H.P., 120 volts; E and F, 6 H.P. each, 240 volts; besides these motors, which are shunt wound, 6 arc lamps of 1000 candle power, 4 of 2000 candle power, and a few glow lamps are supplied. It is evident that the potential between two adjacent mains is a quarter of the whole, being in this case 120 volts, and the motors and lamps are connected to such mains as will give the required fraction of the whole voltage of 480. With the same percentage of loss in the mains, the cost with this system is a quarter of what it would be with an ordinary 120 volt system; for regulating, no apparatus is required except a hand regulator and a voltmeter. The arc lamps are connected two in series, 60 to 65 volts being necessary for steady burning; the different motors are provided with switches and cut-outs to provide safety against short circuits. The mains used weigh about 1 lb. per yard, or 880 lbs. for the 880 yards, the total cost being about £40. Had a direct 120-volt system been employed instead of the 480 volts, it would have been necessary to use, for the same percentage of loss, mains sixteen times the section, viz., 1 square inch, instead of ·06 square inch. As single cable of 1 square inch section would be very difficult to deal with, a stranded cable would be required, which would be 10 per cent. heavier, so that the

total weight would be $16 \times 880 + 10$ per cent. $= 7$ tons; the price for such would also be higher, about $12\frac{1}{2}$ per cent., the total cost then being £792. The cost of the copper, independent of greater cost of putting down and insulation, is thus for a 120-volt system £792 compared with £40 for a 480-volt five-wire system. The use of the equalizing dynamo solves the problem of distributing, by means of continuous currents, to distances and under circumstances when an ordinary direct method would be pro-

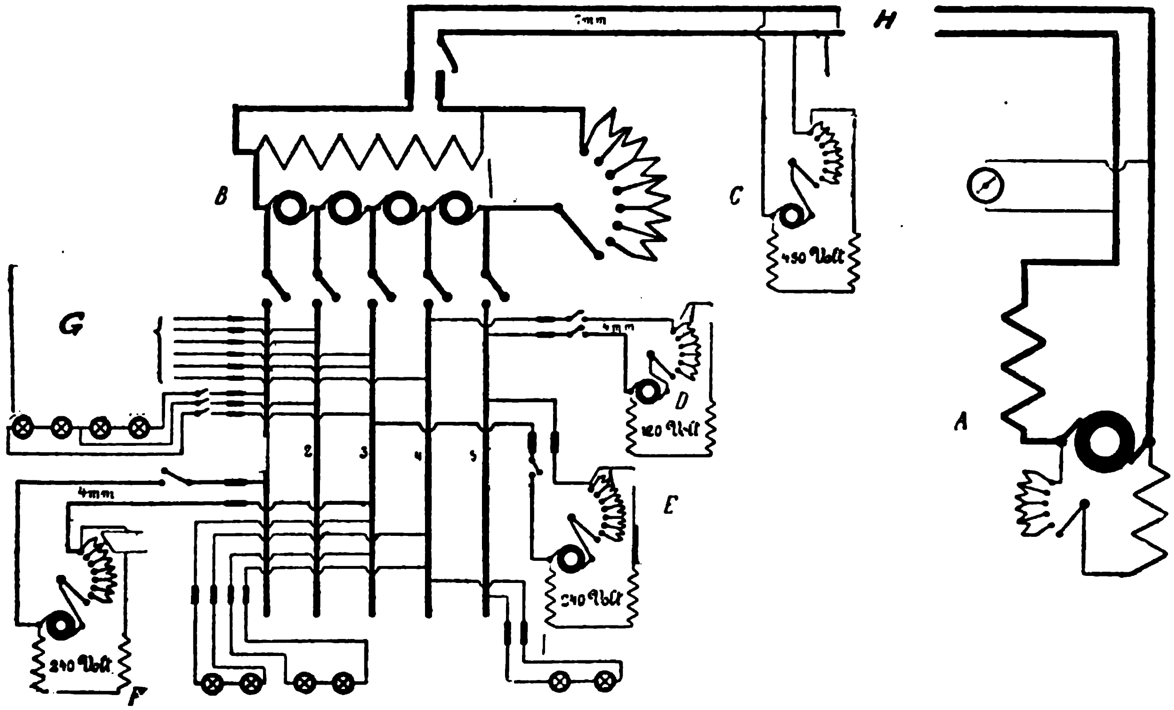


FIG. 103.—DIAGRAM OF SYSTEM WITH EQUALIZING DYNAMO.

hibited by the excessive cost of the necessary mains; a small installation on this system was shown by the Esslingen Maschinenfabrik at the Frankfort Exhibition. Fig. 104 shows the steam engine and generating dynamo, which gives a current of about 125 amperes at 480 volts; Fig. 105, the equalizing dynamo, having only one magnetic field, but four commutators for supplying the five mains.

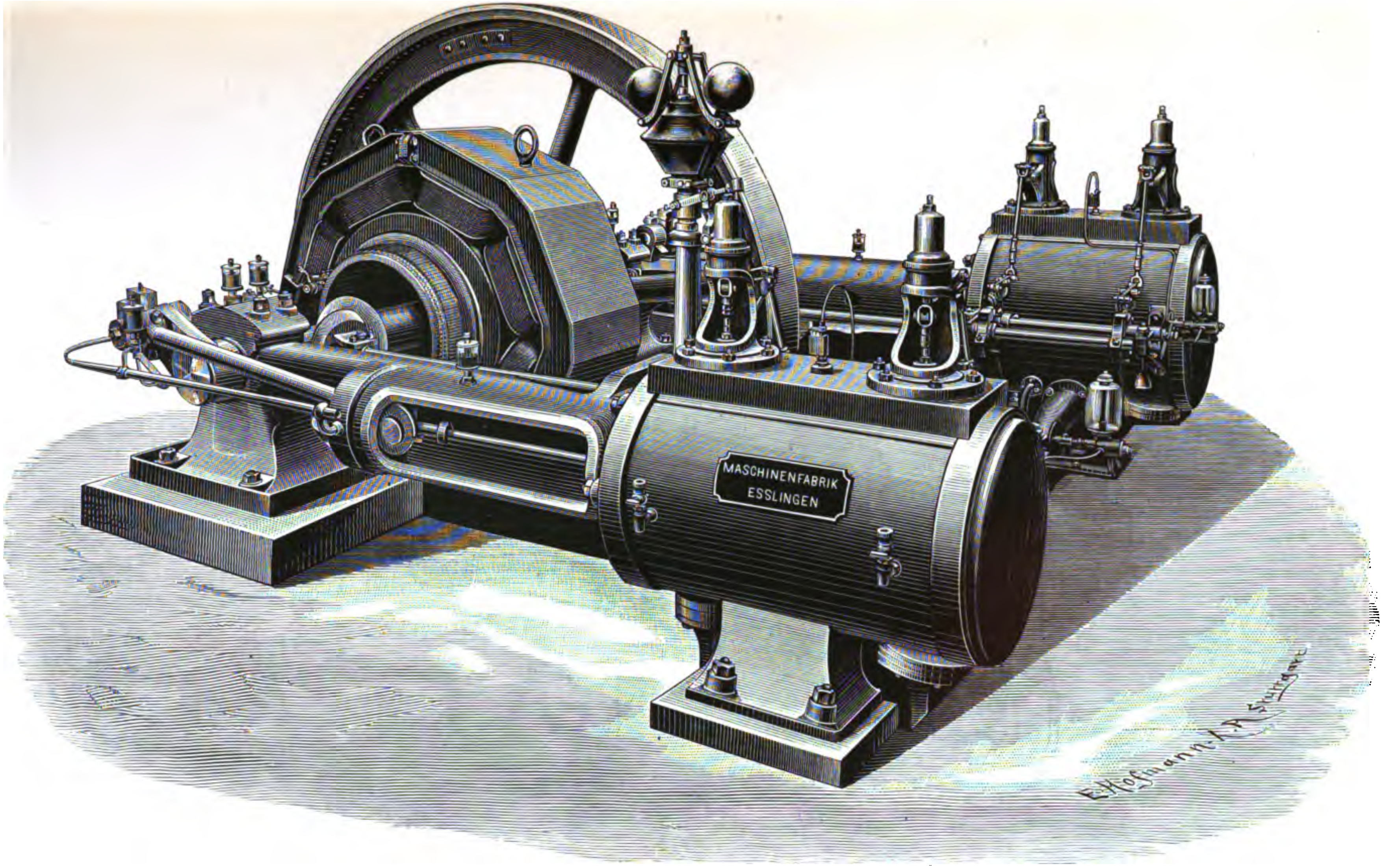


FIG. 104.—ENGINE AND DYNAMO, ESSLINGEN.

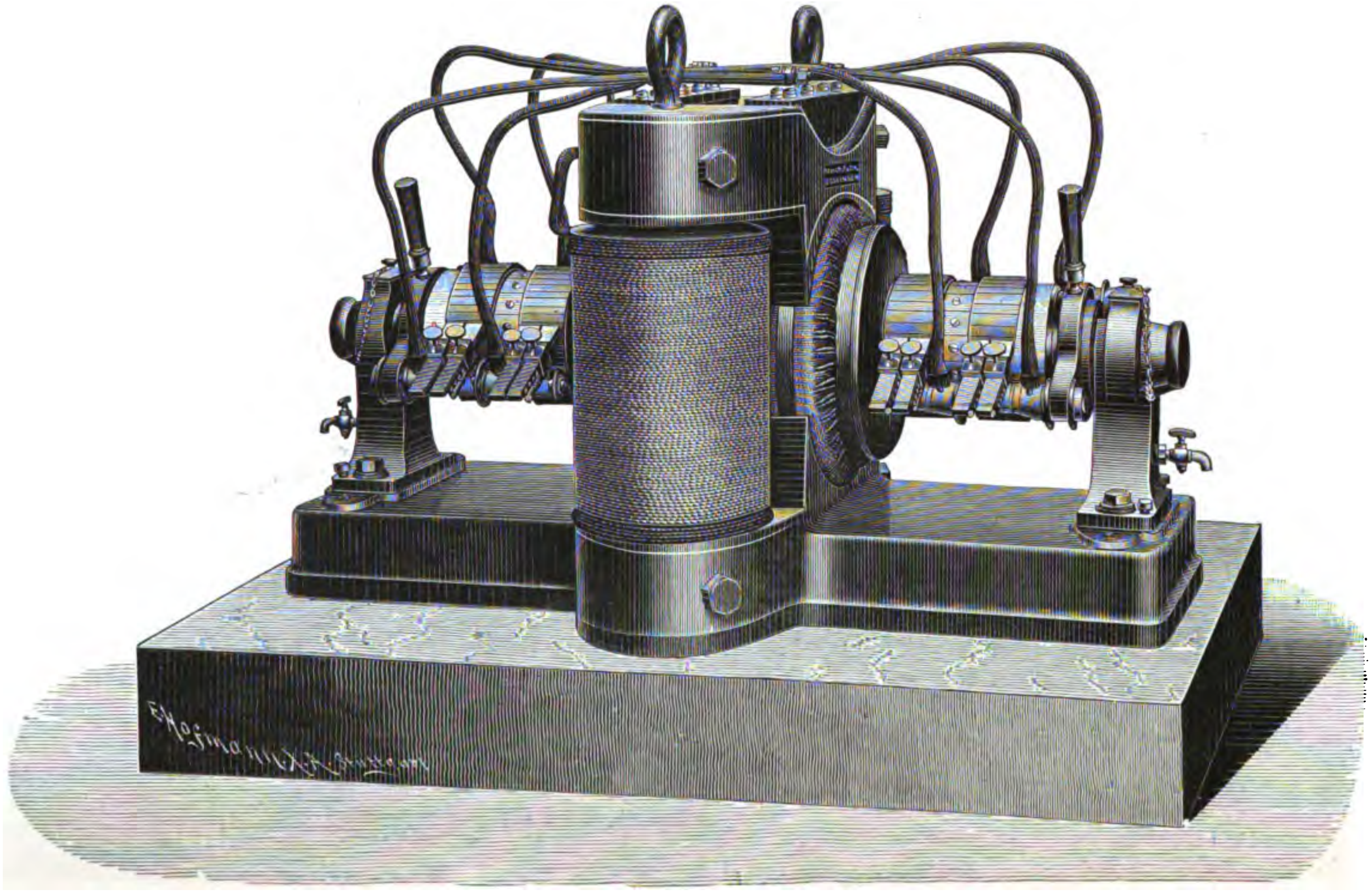


FIG. 105.—EQUALIZING DYNAMO, ESSLINGEN.

THE LIGHTING OF KÖNIGSBERG AND BLANKENBURG,

BY CONTINUOUS CURRENT WITH ACCUMULATORS ON THE THREE-WIRE AND FIVE-WIRE SYSTEMS;

ALSO

THE INSTALLATION AT THE BERLIN HOSPITAL.

By Naglo Brothers, Berlin.

KÖNIGSBERG.

This central station was projected for 8000 glow-lamps of 16 candle-power, and was commenced in September, 1889, current being first supplied on October 1st, 1890; the distributing mains were designed on the five-wire system, to be sufficient for 30,000 lamps. The supply is at present confined chiefly to the shops, business houses and restaurants, but it is intended to provide for the street lighting and also power to work motors. The plan has been adopted of taking two of the five wires into those houses which have a consumption of only 12 amperes or less, three wires for 12-24 amperes, four wires for 24-36 amperes, and above that amount all five leads; the total electromotive force is 440 volts or 110 at the lamps. The central station had to be placed in an unfavourable position, away from the point of greatest consumption; the district supplied also was very narrow, though extending to a considerable distance. The mains are laid underground in conduits, of which Fig. 106 shows a section, with the porcelain insulators, on which are fastened the bare copper conductors, sometimes as many as fifteen in number. Flexible S-shaped pieces of copper are introduced at intervals to allow for the expansion and contraction due to changes of temperature. Fig. 107 is an illustration of a distributing box where the connections are made to the feeders through the copper rings, *a a*, of which there are five. Sufficient space is allowed within these rings to make them accessible for testing and jointing. A great advantage of this system is that by the ventilation of the conduits, the heat generated in the conductors is carried off, and, the insulators being kept dry, the insulation does not deteriorate.

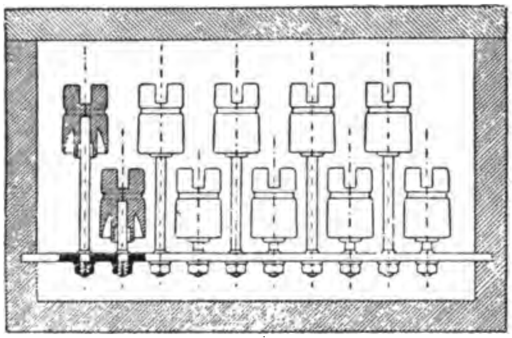


Fig. 106.—CONDUIT, KONIGSBERG.

Plate XXI. is a plan of the Königsberg Central Station. There are two sets of engines and dynamos, being respectively of 32,000 and 64,000 watts output; these dynamos give an electromotive force of from 90 to 160 volts, the higher voltage being required when charging the accumulators. The smaller machines have four and the

larger six field magnets, fastened to the bedplate of the engines, the external armatures being coupled directly to the engine shaft. The triple expansion engines are of 100 H.P. and 200 H.P., and run at a speed of 200 revolutions per minute, each machine driving two dynamos, which have to charge a secondary battery of 248 Tudor cells, supplied by the Hagen Akkumulatorenfabrik, connected to the mains through automatic multiple switches. Plate XXII. shows the connections of the apparatus employed; the current from the dynamos passes through lead fuses, an automatic switch, an ammeter and a main switch for connecting either to the accumulators or the supply mains. Apparatus is also provided for controlling the electromotive force of the dynamos and that at the feeding points, a differential voltmeter being employed in the latter case to indicate the variations of potential. On the other side of the engine room are the tubular boilers, which supply steam at a pressure of 150 lbs. per square inch. The time of maximum consumption is found to be between 6 and 8 o'clock. The advantages of the electric light have been so well appreciated that the great demand for current has already necessitated an extension of the supply mains; the financial results of the undertaking have also proved satisfactory.

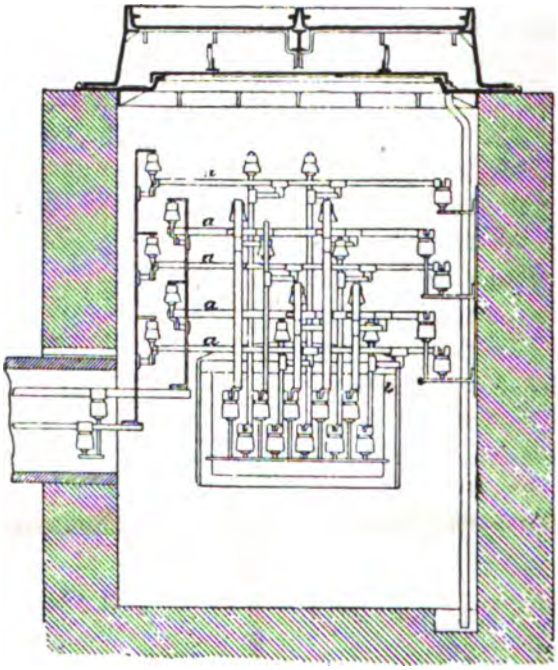
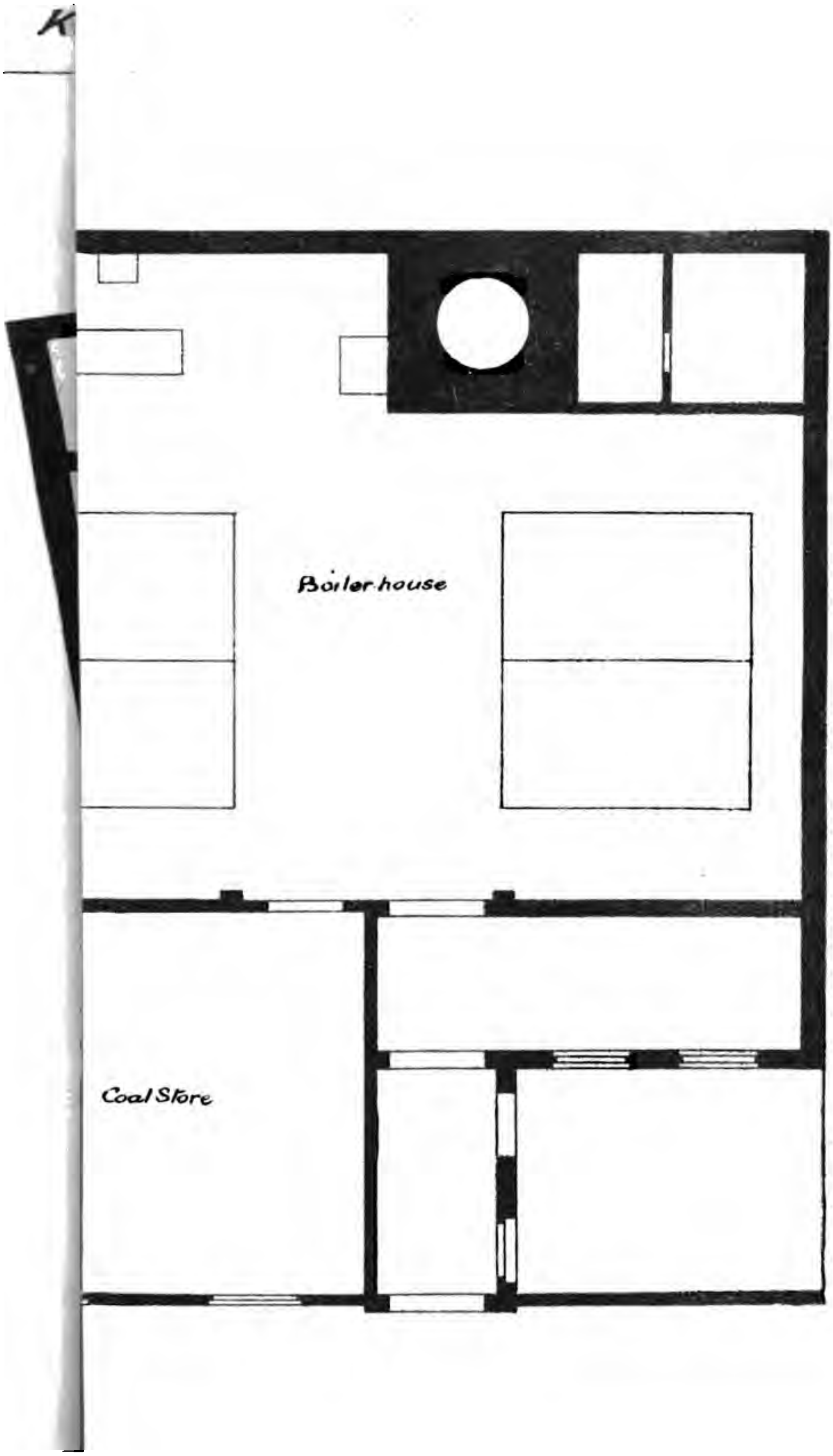
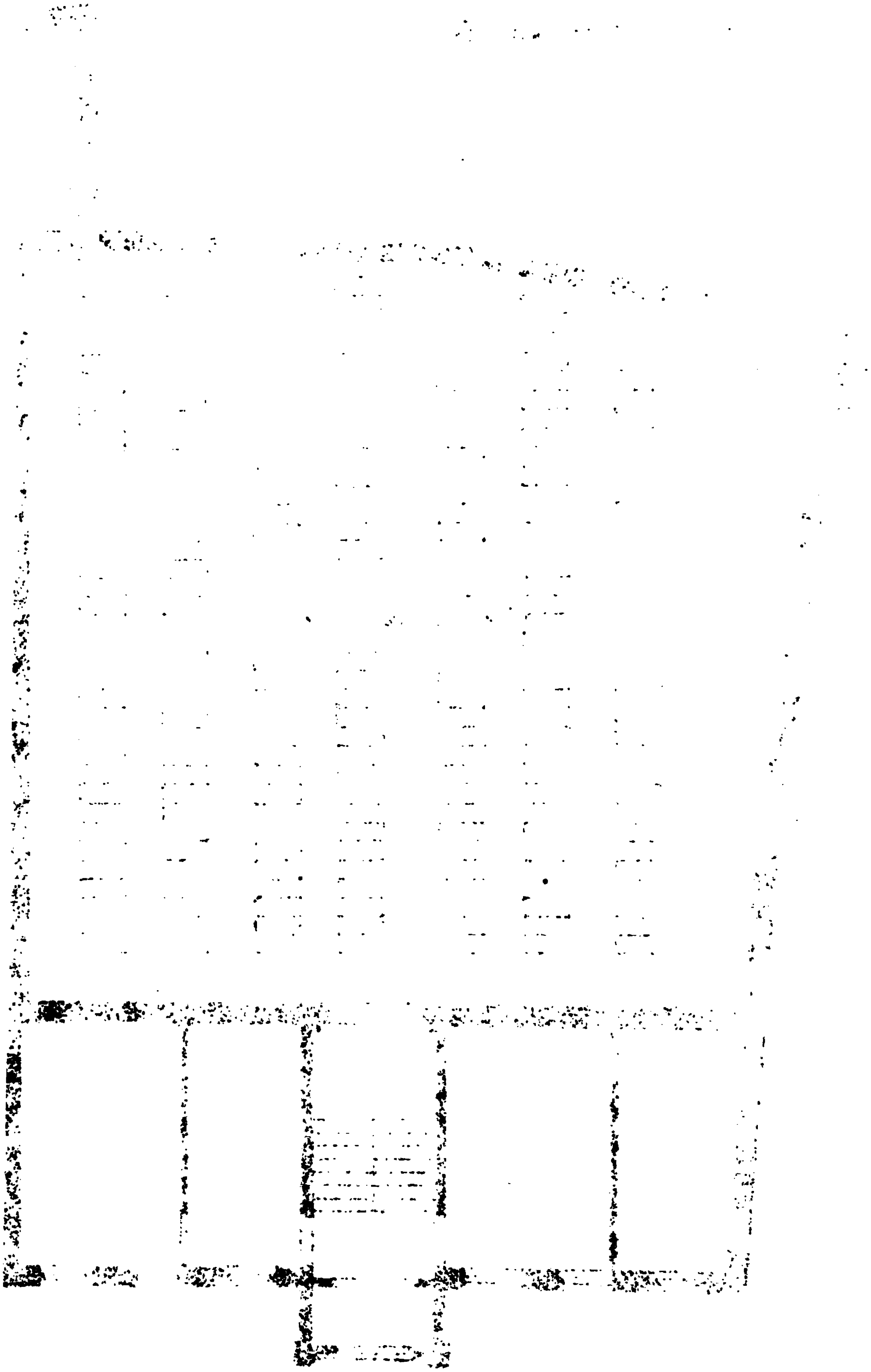


FIG. 107.—DISTRIBUTING BOX, KONIGSBERG.

Plate XXI.





BLANKENBURG.

The great increase in the commerce of the city of Blankenburg (Brunswick), during the year 1890, made it advisable to establish a suitable installation for properly lighting the town.

Blankenburg lies in a hollow, surrounded by high mountains, and covers an area of nearly one square mile, and is rapidly increasing.

The proposal of erecting an electric light station was submitted to a number of firms, and of the various plans suggested that of the firm of Naglo, of Berlin, was accepted.

After careful consideration it was decided to use continuous currents exclusively, and, for the sake of economy, a three-wire system of distribution. The town is divided into three districts, with feeders connecting the central station with the points where there is the greatest demand for current. All the different circuits are protected against overloading by lead fuses, lightning protectors also being placed at various points of the network. On account of the lower cost compared with underground mains, and also the rocky nature of the ground under the streets, overhead wires were employed, consisting of bare copper, except where their proximity to the telegraph lines necessitated the employment of insulated mains. These are carried partly on wooden poles and partly on iron standards; in some places also on brackets fastened to the fronts of the houses.

This installation is capable of supplying about 1000 glow lamps of 16 candle-power or their equivalent; there are about 200 lamps of higher power, and a large number of arc lamps used for lighting the streets and squares. The glow lamps are provided with enamelled reflectors; the arc lamps, which are put on ornamental wrought-iron standards, can be let down for putting in carbons.

Plate XXIII. shows a ground plan of the Blankenburg station. In the acccumulator room there are at present 132 Tudor secondary batteries, supplied by the Hagen Akkumulatorenfabrik, another room over this being ready for further extensions. Two dynamos are employed, giving 210 amperes each at 125 volts, provision having been made also for two more; these are driven by belting from one steam engine, a second engine of similar size being in reserve, and so placed that it can be immediately brought into action if required.

Plate XXIV. shows a diagram of the electrical apparatus. The three districts supplied are connected to the station by the feeders, testing wires being used to indicate whether the potential is normal. After about 11 o'clock in the evening the engines stop, and the secondary batteries supply the current.

Two tubular boilers are used, with a steam pressure of 130 lbs. per square inch; these will together evaporate 2,600 lbs. of steam per hour. The water for the boilers is taken from the town supply by pumps and injectors.

The price charged for current varies from $\frac{1}{2}d.$ (4 pf.) per lamp hour (50 watts),

with a total supply for the year of 5000 lamp hours, to ·36*d.* (3·09 pf.) if the consumer uses 90,000 lamp hours; arc lamps of 500 candle-power are charged 2½*d.* per hour, and 1000 candle-power lamps 5*d.* per hour. If the current is used for motors, 2½*d.* is the cost per horse-power hour if 10,000 horse-power hours of electric energy are used in the year, 1·9*d.* per hour being charged for each additional horse-power after the first.

ELECTRIC LIGHTING OF THE BERLIN HOSPITAL.

This hospital was built in the years 1889 and 1890 with all the latest improvements, and for lighting it an electrical installation was erected. The mains are arranged in two different circuits, quite independent of one another, so that any accident should only affect part of the lamps in each room.

The engines are placed under the management offices; the boilers, of which there are six, supply steam for heating the building as well as for working the engines. The separate pavilions of the hospital are connected by underground passages, where the steam and water pipes are placed, and are used for the electric light mains.

The steam engines consist of two compound 75 H.P. machines, running at a speed of 130 revolutions per minute, each driving a shunt-wound dynamo at 350 revolutions. These dynamos have outputs of 400 amperes at 110 volts, and 300 amperes at 150 volts. The machines have separate foundations, and are surrounded with cork to deaden the vibration. The accumulator room is placed next to the engine room, the switch-board being placed on the dividing wall; 124 Tudor cells are in use, connected in two sets, so that the whole battery will take a charging current of 350 amperes, having a capacity of 2,200 ampere-hours.

The mains are carried on porcelain insulators fastened to iron supports. On the switch-board there are ammeters for each dynamo and for the cells, the latter being also provided with indicators to show whether the batteries are being charged or discharged. Automatic switches are used to keep the potential constant, 1·5 volts being the greatest variation possible. The dynamos are regulated by means of resistances in the shunt circuits. If the automatic switches should fail to act, or for any other reason the electromotive force should rise above 112 volts or fall below 106 volts, a relay brings an alarm into action; on the multiple charging switch for the secondary batteries there is an arrangement for separately measuring the electromotive force of each cell.

The circuits of each pavilion are provided with separate switches and fuses; in the wards the lamps have regulating resistances, to enable the intensity of the light to be varied. Electric light arranged in this way is exceptionally suitable for such an institution as a hospital, there being very little heat radiated, and nothing to con-

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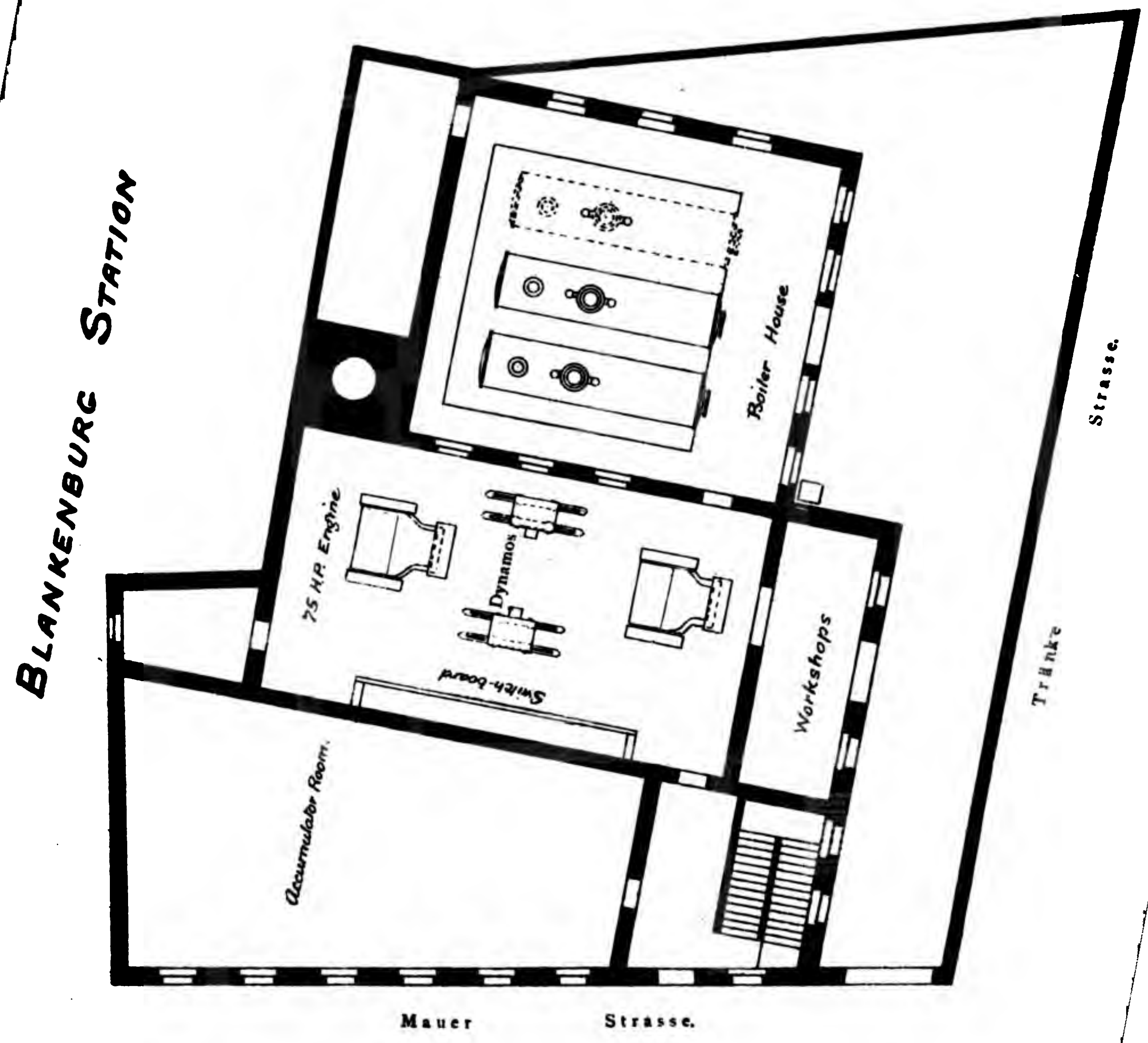
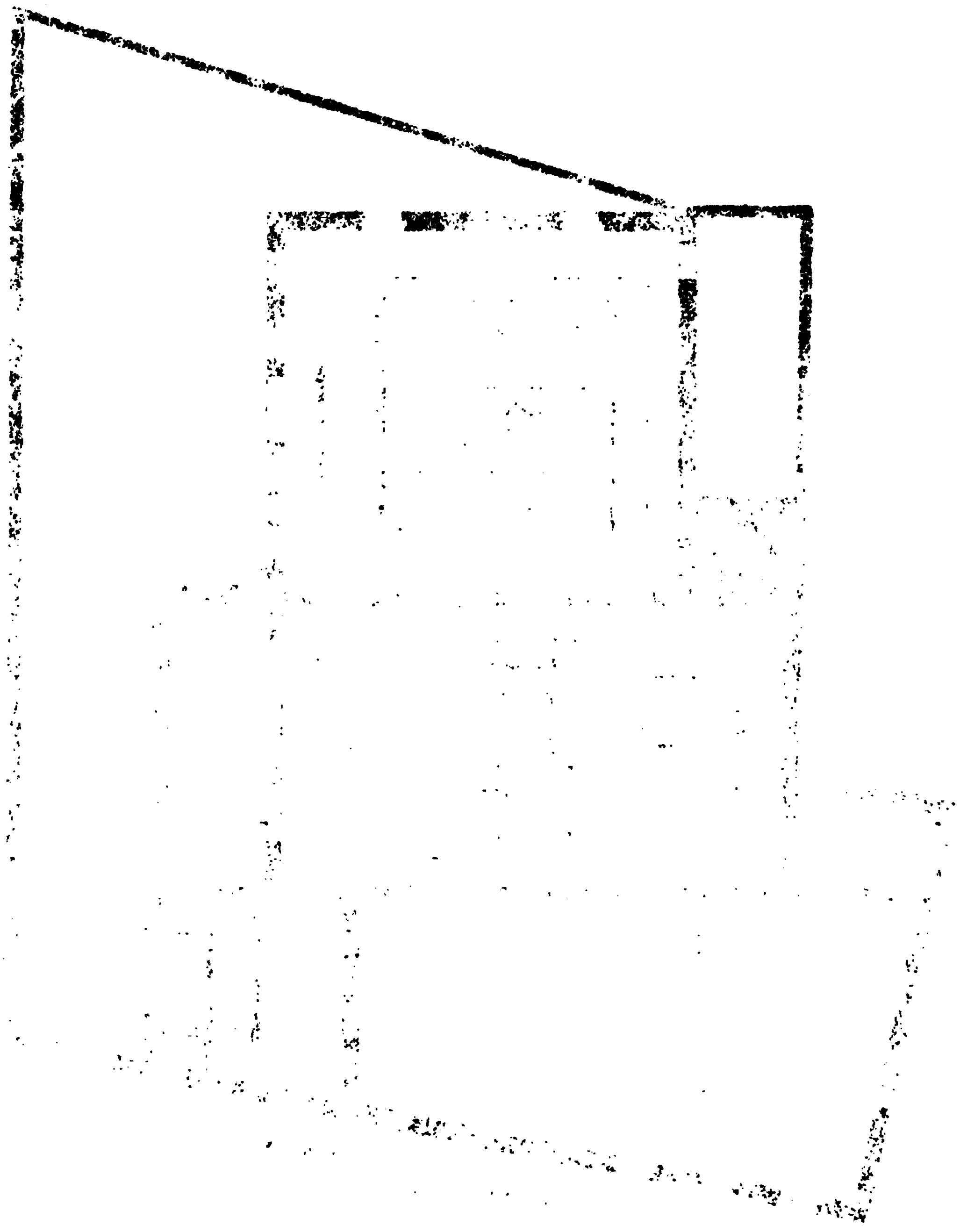


Blankenburg Station
Boiler House
75 H.P. Engine
Dynamos
Switch-board
Workshops
Accumulator Room.
Mauer Strasse.
Tränke Strasse.



p.15.

taminate the air. The operating room is lighted by an arc lamp; arrangements are made to supply current, at about 3 volts, for electric cautery.

In the winter, the accumulators are charged from 9 to 3 o'clock; from then until 9 o'clock in the evening the dynamos and cells together supply the current, and after that the cells alone. In the summer, only about three hours (9 to 12 o'clock) are necessary to keep the accumulators charged.

As previously stated, the use of cork prevents any vibration being noticed in any part of the building. The whole installation has given complete satisfaction.

THE ELECTRIC LIGHTING OF MILAN.

BY THE EDISON AND THOMSON-HOUSTON SYSTEMS.

Incandescent lighting has been very extensively introduced throughout Italy, and in all the principal cities central stations are multiplying, while many of the villages are lighted throughout by electricity, the old oil street lamps being replaced by incandescent lamps of 10 candle-power, which are usually suspended under a flat reflector, no lantern being used.

The Societa Italiana di Elettricita, which owns the Edison patents, has erected far the largest number of central stations. Its headquarters are at Milan, where the Edison system of underground mains was first introduced in 1881, and which has now been enormously developed. Important works constructed by this company in Turin, Leghorn, and Venice, are now taken over by local companies. In Milan there are at present two stations; one supplies current on the Edison low-tension system, two-wire and three-wire, and the other high-tension current from Thomson-Houston (series) arc lighting plant. The former distributes current to 650 consumers, representing in their installations a total output of 10,521 amperes at 110 volts electromotive force. The above current is distributed as follows: 4691 10 candle-power lamps, 13,276 16 candle-power lamps, 43 20 candle-power lamps, 278 24 candle-power lamps, 482 32 candle-power lamps, 5 50 candle-power lamps, 1 100 candle-power lamp; making a total of 18,776 incandescent lamps, taking 8750 amperes. In addition, the following arc lamps are on the low-tension circuits: (1) Private consumers—343 6-ampere lamps; 55, 4·5 amperes; 98, 9 amperes; 6, 11 amperes; total 502 arcs, equivalent to 1,633 amperes. (2) Public lighting—26, 4·5 amperes; 3, 6 amperes; 1, 11 amperes; 1, 20 amperes; 1, 35 amperes; total 32 arcs, equivalent to 139 amperes. (3) Current is also being supplied to 15 motors, absorbing 27·75 H.P.

The station supplying the current for the street lights has a capacity of 500 arcs

of 10 amperes, of which there are 275 municipal lamps and 35 for private consumers now at work. The equipment consists of

Four	Thomson-Houston		30-light	dynamos,
Four	„	„	35-light	„
Four	„	„	50-light	„

These are worked by two 90-H.P. and four 60-H.P. Armington and Sims engines; steam is furnished by five 105-H.P. Babcock and Wilcox boilers. The electrical equipment of the Edison low-tension station at present is as follows: ten Edison "Jumbo type" direct-driven dynamos, 750 amperes, 115 volts; two Edison "Standard" dynamos, 240 amperes, 125 volts; and one Sprague 5-H.P. motor, driving a Gramme dynamo, 20 amperes, 120 volts. The power is obtained from seven Armington and Sims and three Porter-Allen engines; ten 165-H.P. Babcock and Wilcox boilers furnish the steam. The stations at Leghorn and Venice are on the Zipernowsky-Déry-Bláthy system of alternating currents, with transformers.*

The Santa Radegonda station at Milan is at the present moment the largest Edison station in Europe. The building, which was formerly a theatre, is well adapted for the work required; the dynamos and engines are fixed in a deep basement, while the boilers are a few feet above the street-level, the upper floors being used as stores and testing-rooms. To control the electromotive force, which varies greatly from time to time, hand regulation is used during the day, with the help of the Edison tell-tale, consisting of two lamps, a red and white one, which light up when the voltage is high or low; but when the night service comes on, as it may happen that two thousand lamps may be turned out at once, an attendant has to carefully watch the electric regulator, and be ready to insert resistance in the field-magnet circuits by moving a wheel connected by a shaft and bevel-gear to a system of commutators. The principal difficulty to be overcome, in an installation where the current is distributed over a large area, is the regulation of the electromotive force at the various points. As at Milan there are no return galvanometer wires, which are now used in both the two and the three-wire Edison systems in the United States, the plan devised by the company's electrician is very ingenious, and enables the pressure at the ends of the various feeders to be kept practically the same, although they are of different lengths and sectional area. In the first place, resistance was added to each feeder to equalize the resistance in each conductor; and in order to provide for the varying amount of current the feeder has to supply a peculiar form of commutator, having a guillotine-shaped contact-piece, inserted in the circuit. By moving this, suitable resistance is inserted or cut out, and the attendant, having a series of numbers, has only to set this instrument to the number shown by the ampere meter. By far the largest amount of current is drawn off for the lighting of the Scala Theatre, the stage-lighting alone taking more than one thousand lights. If these were all turned on suddenly, the other lights in the district would be dimmed. To obviate this, auxiliary feeders have been run, which are used only when any great increase is

* *See* pages 13 and 16.

expected. Commutators similar to those referred to above also regulate these feeders without any special attention. The pressure at any point in the system is by this means easily controlled, and affords an illustration of what is perhaps not the most economical but is found to be the most practicable way of maintaining a constant potential in a district where the amount of output of current is suddenly doubled. Fig. 107 (*a*) is a plan of the network system of conductors laid through a large portion of the city; the conductors are in outward appearance similar to gas-pipes, the current passing through semicircular bars of copper, imbedded both for the flow and return in the same iron tube, which is laid underground in a shallow trench. The house-supply is drawn from the mains, and these are connected to the feeders by means of ordinary junction-boxes, which each contain a fusible cut-out. The bridge-boxes allow of

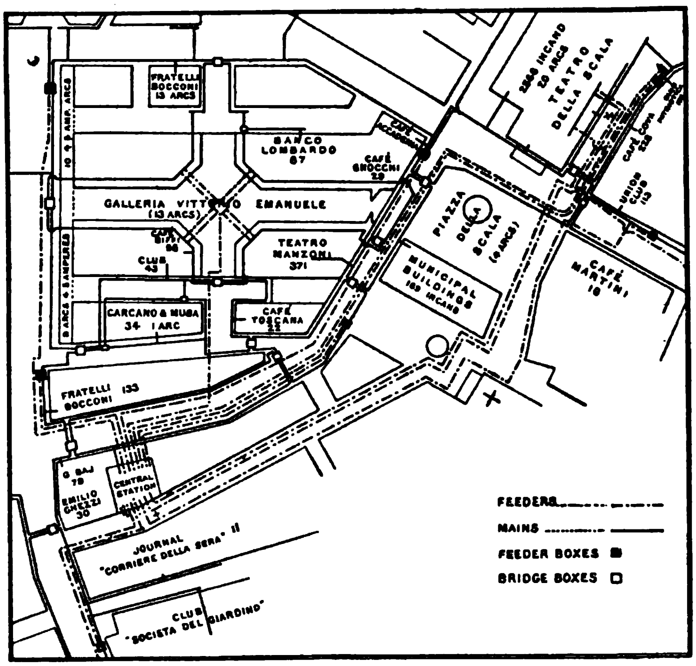


FIG. 107 (*a*).—PLAN OF NETWORK, MILAN.

expansion of the line, and have connections for testing purposes. The insulation is extremely good, mainly on account of the favourable nature of the ground, which is chiefly gravel; no trouble has been experienced with leakage, nor has the service ever been interrupted. The cut-outs are of an improved Edison form, but have the disadvantage attending all lead plugs where the current is great, in that, to guard against accidental melting due to the heating effect of the current, the sectional area of the lead has to be much larger than would be otherwise necessary. In fact, these cut-outs will protect the cable against a bad short-circuit but nothing else.

In addition to the glow lamps, arc lamps are worked in derivation, two in series. Most of these lamps require 45 volts, to which 10 per cent. of idle resistance is added, constituting a total loss of current which is extremely low for a combined arc and incandescent system of lighting. The service commenced with a little over one hundred

lamps. At first the new enterprise had to struggle against very great difficulties; not only the technical difficulties of distribution by means of a network of feeders and mains had to be overcome, but also those arising from the prejudices of consumers and the competition of the gas company, who tried to deter consumers from introducing electric light into their houses. One of these means consisted in offering to the private consumers resident in the district which was threatened by competition with electricity an agreement, by which the gas company bound itself to supply gas at 5*s.* 8½*d.* per 1000 cubic feet instead of 7*s.* 7*d.* as charged hitherto; and even now those inside the "charmed circle" of the electric-light conductors get their gas cheaper than the public outside. One of the reasons which accelerated the adoption of electric light was the introduction of the Edison meter, in consequence of which consumers could be charged exactly for the amount of light they had received, and were relieved from paying a lump sum according to the number of lamps fixed, which was customary in the early days of the company. The prices at which the company now provides light, at all hours of the day and night, are as under:—

Type of lamp.	Installation charge per lamp.	Charge per lamp hour.
	s.	*d.*
10-candle . . .	18	0·26
16- " . . .	28	0·40
32- " . . .	56	0·80

that is, a little over ½*d.* per ampere-hour, the 10-candle lamps requiring 0·5, the 16-candle lamps 0·75, and the 32-candle lamps 1·5 ampere.

The company lends meters for 50, 100, and 150 lamps, at an annual rent of 4*s.* 10*d.*, 7*s.* 3*d.*, and 9*s.* 7*d.* respectively, and replaces, without charge to the consumer, any lamp the filament of which has broken, but it does not replace lamps where the glass is broken. For arc lamps requiring 9 to 10 amperes, an annual rent of £2 must be paid for the lamp itself, and a charge of a little over ½*d.* per hour for every ampere-hour. The carbons are charged for at 1*d.* per pair, lasting for about seven hours. Now that the installation has been in use for several years, and that the company has arrived at a very accurate estimate of the time during which an average consumer requires the light—about 1600 lamp-hours per annum—it proposes to simplify the method of charging large consumers, by omitting the initial charge of each lamp and, instead, to charge 0·5*d.* for each 16-candle lamp-hour.

The Edison meters are based on the electrolytic action of a small fraction of the current which passes through the meter. They are cells, with rectangular zinc plates immersed in a solution of sulphate of zinc of 1·054 density, the distance between the plates being a little over ¼ inch. The proportion of the current which passes through the meter to that which passes directly into the consumer's house is 1 to 973. The resistance of the shunt circuit is 9·75 ohms, made up as follows: cell, 1·75 ohm; metallic portion, 8 ohms. The resistance of the metallic portion rises with the temperature, whereas that of the cells falls with a rising temperature; and in

this manner the small variations of resistance which might take place in the cell are counterbalanced by the equally small variations in the resistance of the metallic portion. A complete meter consists of two similar-sized cells of the same resistance, placed in series. The object of employing two cells is, that when little current is passing, as in the summer months, one cell alone is used, and when the consumption is sufficiently large both cells are employed, and the mean between the two indications is taken as the basis for calculation in number of ampere-hours. The quantity of electricity passed through the cell is calculated by the loss of weight which has taken place in the positive plate. An employee of the society visits every meter monthly, taking away the old cells and substituting others freshly constructed. A book is kept in which the weights of the new plates and those of the returned plates are entered, and on the basis of these entries the accounts are made up. The largest plates are those in the 100-light meter, and are intended for a maximum current of 75 amperes in the main circuit; they are six inches long by two inches wide. In cases where a larger amount of current is taken, the capacity of the 100-light meter is increased by joining two or more copper strips across the terminals of the cells. The weak point of the system is the removal of the cells, which leaves the adjustment of the account to be paid entirely in the hands of the Electric Light Company. In spite of this drawback, it is stated that there are few complaints from consumers. A modified form of electrolytic meter is now being introduced, which obviates the necessity of removing the plates by automatically registering their increase in weight.

THE THOMSON-HOUSTON SYSTEM.

The street arc-lighting at Milan is perhaps not so striking as that at Turin. The broad streets, which resemble those in an American city, are excellently lighted on a plan which perhaps does not commend itself from the architectural view, but the small detraction of the overhead wires stretching across the thoroughfares, in order to support the arc lamps, is amply compensated for by the equality of the illumination. The Thomson-Houston lamps are fixed at such a height that they do not fatigue the eye, and are well out of the way of the traffic. With the exception, perhaps, of a fire-escape, which has to be removed at a rather low angle of inclination, no vehicle could be loaded sufficiently high to interfere with the lamps. This method of overhead suspension is almost universally adopted; in Turin and Milan the lamps are fixtures, and the carbons are renewed every morning by means of a balanced ladder fixed to a trolly, which contains the necessary material and spare parts to replace breakages. Two men do the work very quickly, and the stoppage at each lamp is not long enough to interfere with the traffic, which, even at the early hours chosen, is about the same as it would be at home. At Genoa the lamps are lowered by means of a wire rope, and the leads, which are fastened to insulators on one side of the street, cause the

lamp to be delivered on to the pavement. In every city overhead wires are permitted, so long as they do not cross the streets; they follow the line of the houses and are carried on insulators fixed to brackets about the height of the first floor, in the same way as the telephone and telegraph wire are generally run abroad. The advantage claimed for this system of arc-lighting is that the length of the mains can be practically unlimited. For maintaining arc lamps, dynamos are made which will supply 50 in series of 2000-candle power, requiring 10 amperes; in Quebec there is a circuit extending a distance of 22 miles, in order to utilize the existing water-power. In January, 1891, 716 American electric light companies had adopted the Thomson-Houston arc lamp, and during the last three years the minimum yearly increase of lamps was about 16,000; also, out of 33,371 arc lamps employed for street lighting in the United States in November, 1890, in various towns, 22,431 were on the Thomson-Houston system, which has been adopted for the following European towns:—

Milan . . .	250 lamps.	Turin . . .	216 lamps.
Paris . . .	100 „	Marseilles . .	150 „
Saint Brieux . .		Bilboa . . .	46 „
Gothenburg . .	39 „	Hernösand . .	50 „
Hammerfest . .		Helsingfors . .	

THE IMPERIAL CONTINENTAL GAS ASSOCIATION'S STATION, VIENNA.

The practical success of the battery transformer system has been demonstrated at Vienna, where an installation of five thousand lamps, equivalent to 15,000 16 candle-power lamps, in the Opera House and Burg Theatre, was designed and erected by Messrs. Crompton in 1887, the current being taken from a central station 1,400 yards away. The boilers are fixed in a basement formed by excavating the court-yard of a private house to a depth of 15 feet 6 in. below the street level; the building itself is utilized partly for offices and partly as a large dynamo and engine room. The plant in the station now consists of six Willans-Crompton steam dynamos, three of which are of 100,000 watts each, and three of 60,000 watts; there is also an Oerlikon steam dynamo, having an output of 300 amperes at 400 volts when running at 140 revolutions per minute. Steam is furnished by eight Babcock-Wilcox boilers, each of 142 square feet heating surface, and working at 150 lbs pressure; the fuel employed is coke, as the authorities forbid the use of coal in any works inside the inner town. From the switch-board the current is taken to the two theatres by lead-sheathed cables, each having a sectional area of ·7 in., which are laid in a bricked-in trench about 4 ft. underground. In the bottom of the trench are wood planks, which have been steeped in paraffin. The grouping of the secondary batteries in the two theatres

is almost identical, each having its own set working almost independently of the other. In the first place, the batteries are divided into three main groups, coupled together on a simple parallel system; one is used exclusively for the stage, the other two serving to light the rest of the house. All the lamps are on 100-volt circuits. Each of the three main batteries is again subdivided into three or four series, coupled parallel

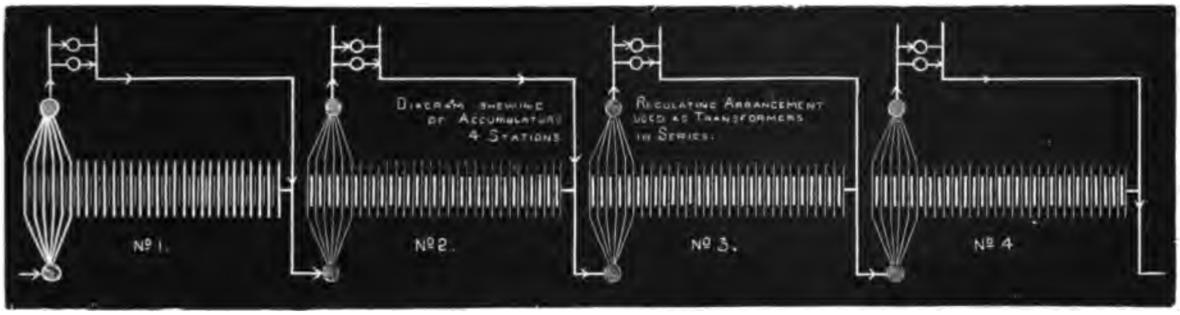


FIG. 108 (*a*).—BATTERY TRANSFORMER.

at their ends. In a series there are 54 or 56 cells—the normal rate of discharge is about 200 amperes. Fig. 108 (*a*) shows the arrangement; the current may be supposed

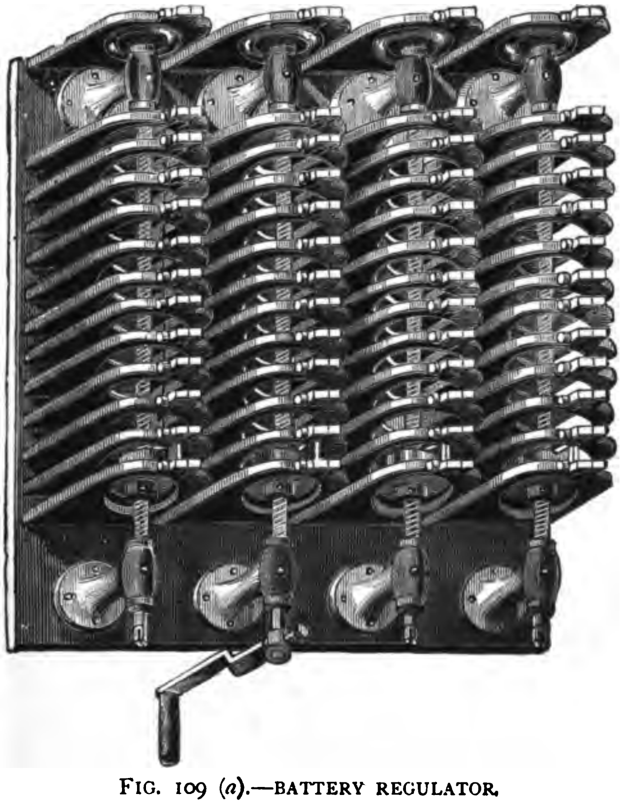


FIG. 109 (*a*).—BATTERY REGULATOR.

to enter at the left-hand corner, passing through the first battery with the lamps parallel to it, and from that battery to the commencement of the next, and so on

through the third and fourth, the current being varied at will at the central station, or kept constant by means of an electrical governor. The potential for each of the four groups of lamps is maintained in the following manner:—In each group one terminal is kept permanently connected to one of the discharge mains and to one of the charging mains; the other terminal can be shifted from cell to cell according to the E. M. F. required in the corresponding lamp circuit by means of a contact regulator. This movable terminal is shown by the bunch of lines at one extremity of each battery group. The rule for charge and discharge is, that the terminal cell at the regulating end of the battery is so arranged that it neither receives nor gives off current, so that there is no loss of energy in the shape of E. M. F. The regulator is shown by Fig. 109 (*a*), but has since been superseded by a lever step by step switch, which enables the changes to be made quicker.

PART III.

TRANSMISSION OF POWER FROM LAUFFEN TO FRANKFORT; ELECTRICAL MEASURING INSTRUMENTS; CONDUITS FOR ELECTRIC MAINS; DISTRIBUTION OF ELECTRICITY COMPARED WITH GAS; LOAD-FACTORS; NETWORK OF MAINS; INTERESTS OF GAS COMPANIES WITH REGARD TO ELECTRIC LIGHTING; CONTINENTAL CENTRAL STATION PRACTICE; COST OF THE ELECTRIC LIGHT ABROAD; RELATIVE COST OF ELECTRICITY AND GAS; EXTRACTS FROM BOARD OF TRADE REGULATIONS; ELECTRICAL MEASUREMENTS; ENGLISH AND FRENCH MEASURES; RESISTANCE OF COPPER WIRE IN ENGLISH AND FRENCH MEASUREMENTS; HOURS OF LIGHTING THROUGHOUT THE YEAR; EXPLANATION OF TECHNICAL TERMS.

THE LAUFFEN-FRANKFORT POWER TRANSMISSION.

The transmission of power from Lauffen to Frankfort, a distance of 175 kilometres (108 miles), is carried out upon a system which is quite novel, and so far no applications of it have been made in this country ; and it will be well to give a short sketch of the system before describing the particular machines in use at Lauffen and Frankfort. Continuous-current motors have already attained a high degree of efficiency, and for the transmission of power to short distances are all that can be desired ; but where power has to be transmitted for long distances, the low potential of the continuous currents usually employed would necessitate the use of conductors of large sections, which would be too costly. It is almost impossible to build continuous-current dynamos for pressures of 1000 to 2000 volts, and it is therefore necessary to seek the solution of the problem of long distance transmission of power in the employment of alternating currents. Alternating-current dynamos have, of course, been in use for some years, but the problem of constructing a good motor to work with alternating currents has exercised many scientific minds, and until recently no satisfactory solution had been found.

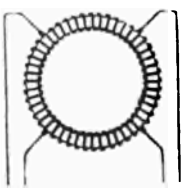


Fig. 1

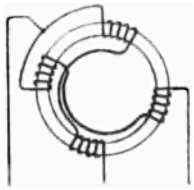


Fig. 2.

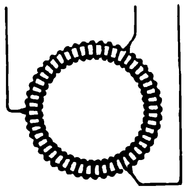


Fig. 3.

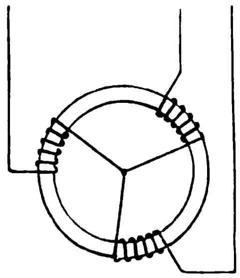


Fig. 4.

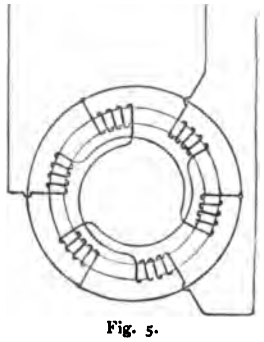


Fig. 5.

Professor Ferraris in Italy, Tesla in the United States, Dobrowolsky, Haselwander and Weström in Germany, and Leblanc in France, had all been working at the problem, and the first published account was that of Ferraris in 1888. Tesla used two alternating currents of the same frequency, but differing in phase by 90 degrees ; but this was found to have decided disadvantages, and more than two currents were afterwards employed. The system of using several alternating currents differing in phase was distinguished as the "rotary-current" system by Mr. Dobrowolsky, for the following reasons :—If a continuous current be passed round the coil of a galvanometer, the needle will be deflected either to the right or left hand according to the direction in which the current is flowing ; if an alternating current be passed round the same coil, the needle will oscillate backwards and forwards ; while if a series of alternating currents differing in phase be passed round the coil, the needle will rotate continuously.

Figs. 1 to 5 show diagramatically the earliest methods of winding the coils with

two or three currents differing in phase, and these were proposed in 1887 by Bradley and Tesla, in the United States. These methods are, however, only slightly better than when ordinary alternating currents are used; the motors suffer from the disadvantages of being unable to start when loaded, and of suddenly stopping when overloaded. In order to work satisfactorily they must synchronize with the dynamo, and before the load is applied must be got up to their proper speed. The great advantage of the rotary-current system of Dobrowolsky is that by its use motors may be built at a low cost which work very economically, and do not need to run synchronously with the dynamo which produces the current. These motors can be started with the load on, and may be overloaded without coming to a standstill. Early in the summer of 1889, the first practicable motor of this class was built by the Allgemeine Elektricitäts Gesellschaft, of Berlin, and they have since built the motors used at the Frankfort Exhibition upon the Lauffen-Frankfort transmission plant. The system differs from that employed by Tesla and others in the fact that, as a rule, more than three phases are used, so that the motors are driven by a series of currents differing in phase but slightly, and for this only three leads are employed. The rotating field in the Tesla motors was not absolutely constant, and with a system of magnets in the form of a ring the intensity of the field can only be kept constant when the number of excited coils remains constant.

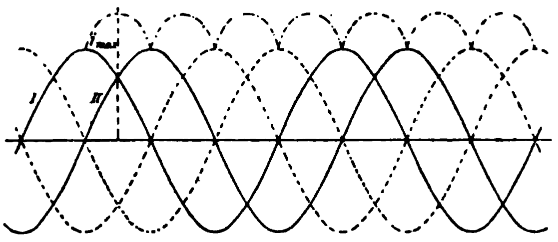


Fig. 6.

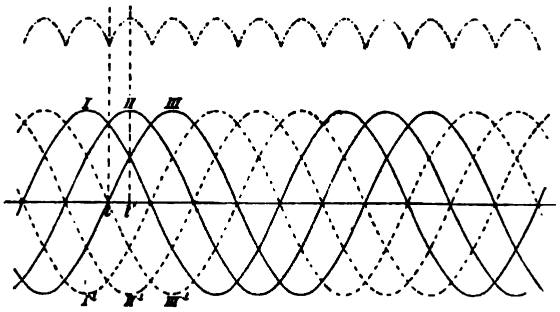


Fig 7

Figs. 6 and 7 clearly show that the sum of the work of several similar currents of varying phases is not constant; the result is that the magnetism is pulsating, and with two currents of 90° difference in phase the pulsations reach 40 per cent., while with three currents differing in phase by 60° they only reach 14 per cent. The amplitude of the pulsations therefore diminishes rapidly as the number of currents employed increases, and with motors built upon the Dobrowolsky system these pulsations should be reduced as much as possible. In the Tesla motor the field is not only rotating, but is also strongly pulsating, as the reader will gather from an examination of Fig. 6, which represents two alternating currents differing in phase by 90°. Fig. 108 represents a small motor of 2 H.P. built upon this system, and coupled direct to a continuous-current dynamo. The three leads will be seen in front, and the current used is that which arrives from Lauffen. The plant was shown at Frankfort at the same stand as the large motor, and a little $\frac{1}{10}$ H.P. motor of the same type was exhibited operating a small fan. In cases where three currents differing in

phase by 60° are used, four conductors are necessary; but where the currents differ in phase by 120°, three wires only are required. Owing to the interlinking of the various currents, it is difficult to regulate the quantity of current flowing in each wire; and as the current flowing in each wire finds its return path through the other two, it is necessary that a balance should be obtained. In order to obviate this difficulty, the separate currents are produced at Lauffen as ordinary alternating currents, and are not interlinked until they reach the three transmission wires; the controlling

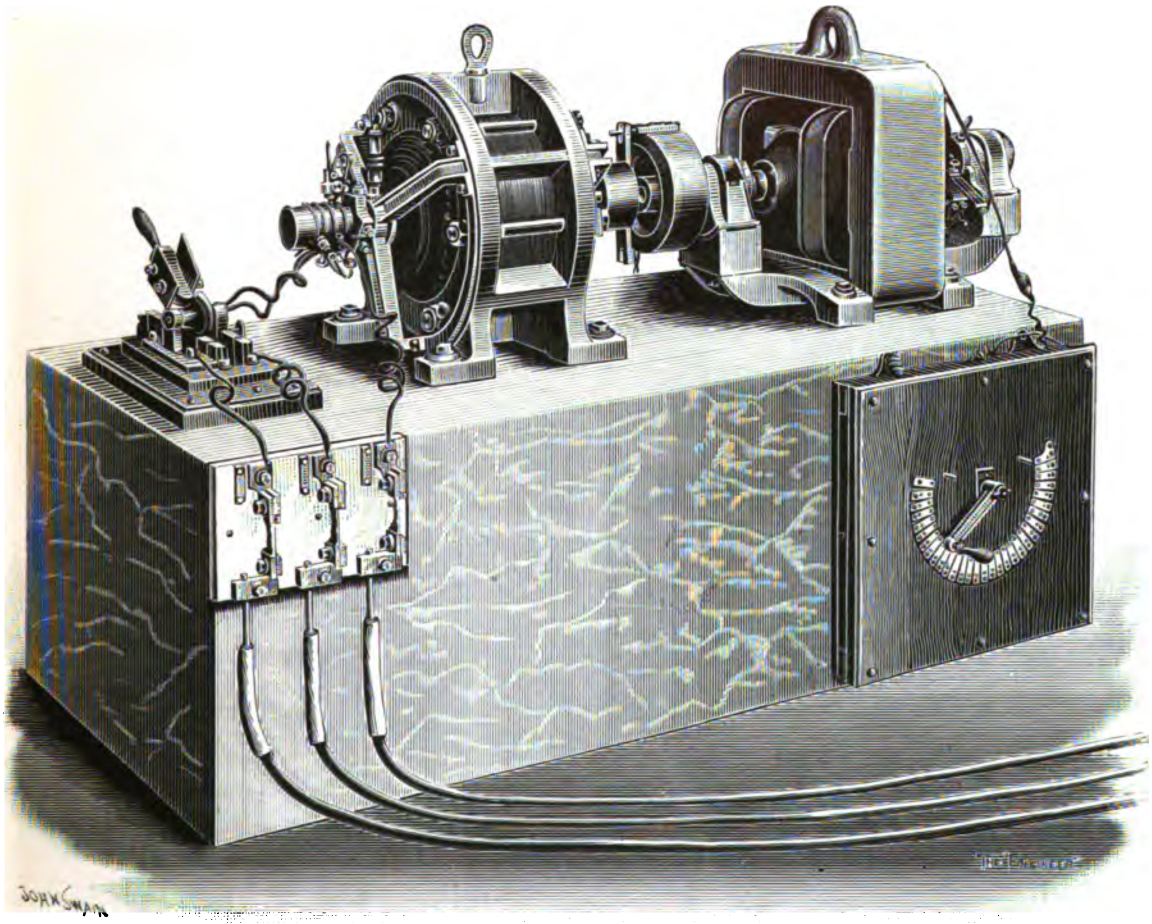
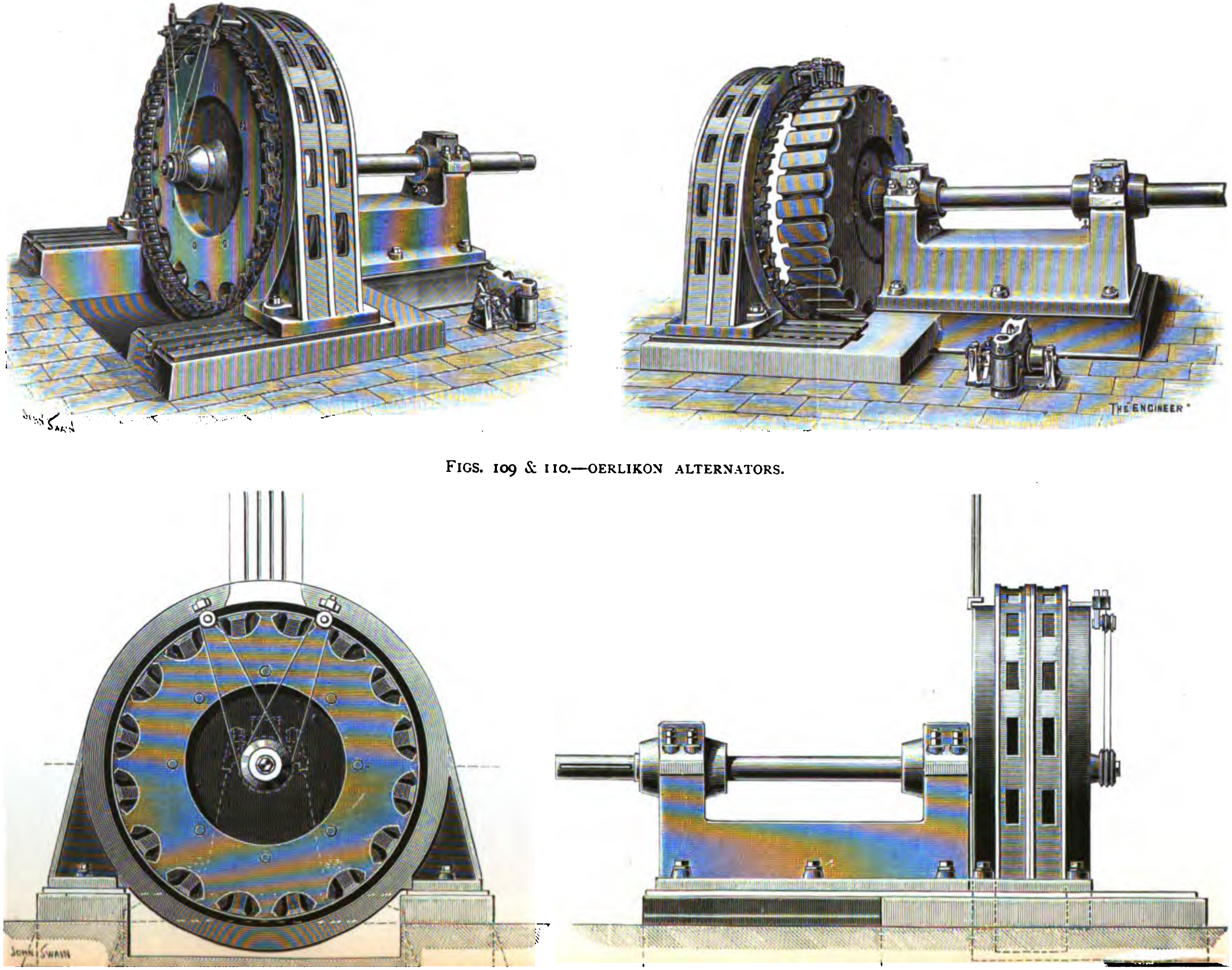


FIG. 108.—ROTARY-CURRENT MOTOR.

apparatus is put into each lead, and it is thus possible to control each main separately.

The transmission is thus effected by three alternating currents, of which the phases differ by 120°, all the currents having the same frequency. Figs. 109 and 110 represent perspective views of the large three-phase alternator, built at the Oerlikon Company's works at Zurich, and Figs. 111 and 112 represent orthographic projections. This machine has been built from the designs of Mr. C. E. L. Brown, and it will be



FIGS. 109 & 110.—OERLIKON ALTERNATORS.

observed that the main shaft runs in two bearings, and that the machine can be easily separated by sliding one half along the base plate, so that a perfect examination can be made. The machine runs at 150 revolutions per minute, and develops 300 H.P. The winding of the armature is arranged so as to produce the three alternating currents previously spoken of; each one of these currents has a mean potential of 50 volts, and is of 1400 amperes. As it would have been very difficult to arrange contact rings in order to take off this large current, the armature has been made stationary, and the field magnets revolve. The winding of the armature is of very large section, corresponding to the heavy currents, and consists of heavy copper bars 1·12 in. in diameter, which are threaded through holes bored in the iron armature core, close to the circumference, the copper bars being insulated by means of asbestos tubes from the core itself. Owing to this arrangement the Foucault currents, which would reach a large amount with the ordinary method of winding, are entirely avoided; and from experiments on such an armature it was found that even when copper bars of 1·96 in. diameter were used it was impossible to measure the energy wasted by the Foucault currents, which must therefore be very small. By the use of such an

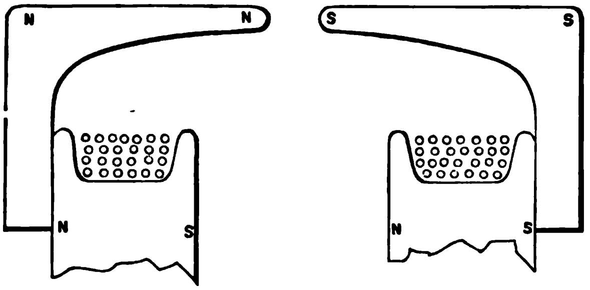


FIG. 113.—METHOD OF FIXING POLE PIECES.

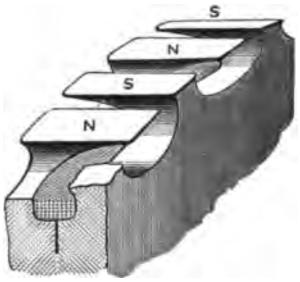


FIG. 114.—POLE PIECES OF ALTERNATOR.

arrangement a direct driving force is applied to the bars, and the asbestos produces a form of insulation which does not suffer from overheating of the wires. The air space between the revolving field magnets and the stationary armature is also in this way much diminished. Armatures of this type for continuous-current machines have been successfully built at Oerlikon since 1885, but an alternator of this class shows more clearly the advantages of the method. The number of field magnet poles is thirty-two, and there are thirty-two copper bars in each armature circuit, which are coupled in series by transverse pieces at their ends; the total number of bars for the three circuits is thus ninety-six. The coupling of the three circuits with each other is effected in a similar manner to that employed in the Thomson-Houston arc light machine. The armature cores are contained in a cast-iron frame, which rests upon the bed-plate, and can be moved in the direction of the axis, as shown in Figs. 110 and 112, so as to allow of an examination of all the parts. The field magnets of the machine are arranged on a simple plan, so that both positive and negative poles are produced by a single exciting coil, which is wound upon a cast-iron ring with two flanges somewhat similar to a rope pulley. This will be more clearly seen in Figs. 113 and 114. Two steel rings, each having upon it sixteen pole pieces, are then fastened by means

of bolts upon the two sides of the cast-iron ring, and the position of the pole pieces is so arranged that those upon one steel ring lie intermediate with those on the other steel ring. Fig. 113 represents in a diagramatic form the method of fixing the pole-piece rings to the drum, and Fig. 114 represents a perspective view of a portion, while Fig. 115 is a plan in section. By this means the exciting coil produces a positive and negative pole alternately in the pole pieces, so that the whole of one steel ring is positive while the other is negative. This arrangement allows of a very simple field magnet winding, and reduces the necessary weight of copper. The construction is

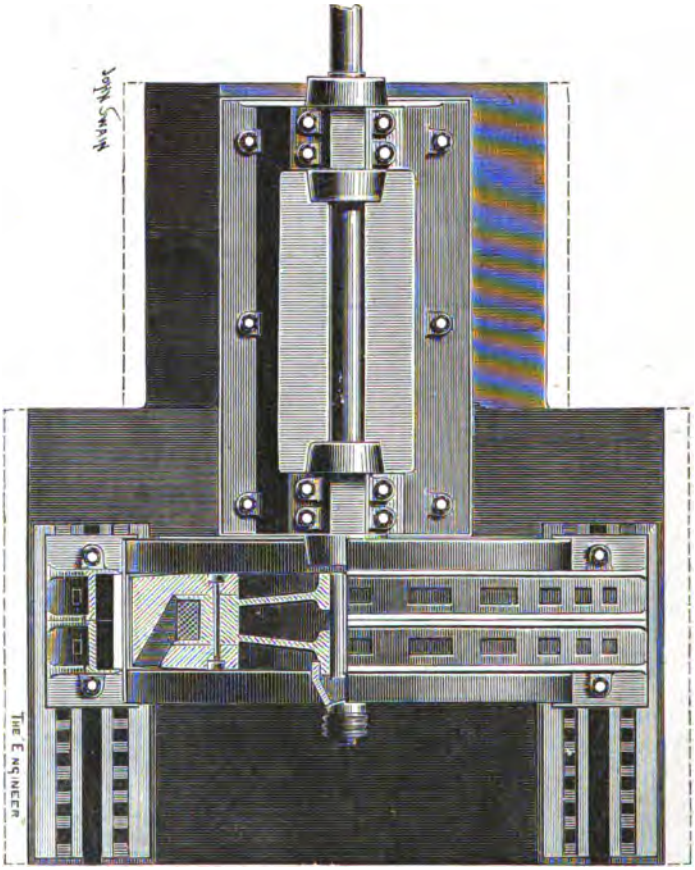


FIG. 115.—PLAN OF ALTERNATOR.

also very simple and strong, as the whole frame and field magnets with thirty-two poles, consists of only four pieces, rendering it exceedingly safe when rotating. The exciting current is led from the two fixed terminals, shown in Figs. 109 and 111, at the top of the machine. Each terminal carries a small pulley, and two grooved pulleys are arranged side by side upon the end of the main shaft; metal bands connect the latter with the terminal pulleys, so that rubbing contacts are entirely avoided. The exciting current is produced by the small dynamo, which may be seen on the ground in Figs. 109 and 110. Fig. 112 will enable the method of fixing the metal bands to be more clearly understood. The main shaft is carried in two bearings, and the casting is fixed

to the base plate. The shaft itself is driven direct from the turbine. The machine which we have just described can work also as a motor, in which case it runs synchronously with the dynamo. It has the advantage, however, over the ordinary alternating-current machine that it can start in any position, the field magnets must, of course, be first excited. The following particulars of the machine may be of interest. The total weight of copper in the field magnets is 660 lbs., which is only a small fraction of that necessary for other machines of similar size and number of revolutions. When running idle at its normal speed, 100 watts is sufficient to excite the magnets in order to produce a potential of 50 volts. This is only $\frac{1}{20}$th per cent. of the output of the machine ; a larger exciting current is, of course, necessary when the machine is working at full load, but even then it is but a fraction of 1 per cent. From the experiments which have been made it appears that when running at a normal speed and potential, the loss in friction, air resistance, hysteresis, &c., only amounted to 600 watts, being only 1·6 to 1·7 per cent. of the total output. The loss in the armature coils at full load reached 3500 watts, so that the total efficiency of the

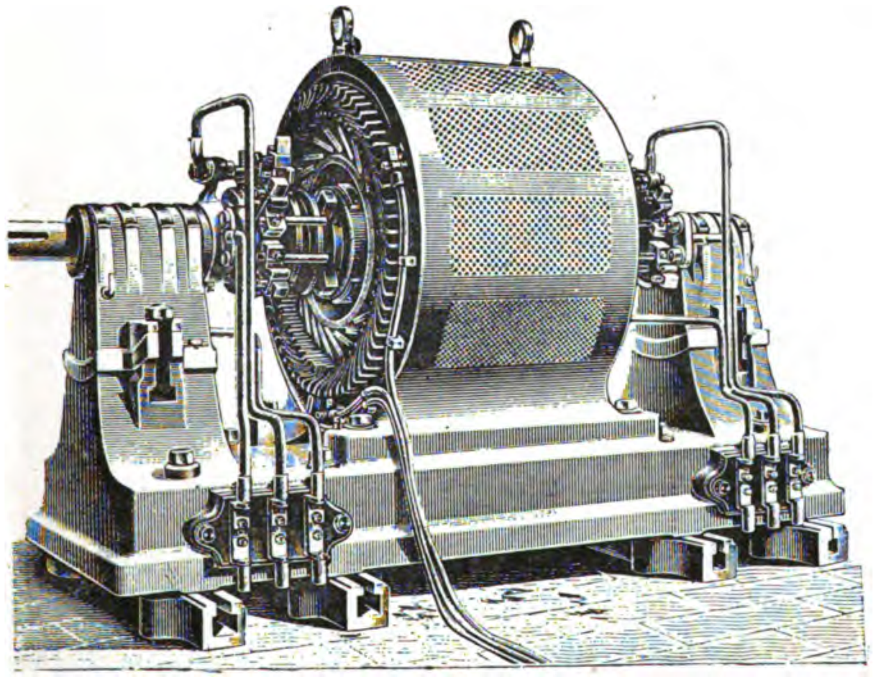


FIG. 116.—DOBROWOLSKY 100-H.P. MOTOR.

machine was about 96 per cent., and it is believed that such a result has never before been obtained with such a simple construction. Owing to the small losses, the heating is, of course, very small, and it is thus possible to overload the machine without producing any ill effect. The total weight, with bed-plate, is 8·8 tons.

Fig. 116 shows the outward appearance of M. Dolivo Dobrowolsky's 100-horse-power motor, which worked the artificial cascade at the Frankfort Exhibition. This three-phase motor in its essential elements consists of two concentric rings of soft

iron, the outer ring acting as a fixed armature, and the inner as a movable inductor. The two rings are pierced with holes parallel to the axis, in which the conductors are inserted, the connections being made by straps which are arranged on the surfaces of both parts; these straps are shown on the drawing.

"The little town of Lauffen is charmingly situated on the river Neckar, which separates it into two halves, connected by an old bridge, which, to say the least of it, has seen better days. The town is chiefly noted for the cement works, said to be the largest on the Continent, and have at their disposal a water power of about 1600-horse power, derived through a separate channel from the river, about one mile above Lauffen. Of these 1600-horse power, the cement works themselves utilize 600 by means of two Girard turbines of 300-horse power each; a third turbine of 300-horse power drives the dynamo generating the current for the power transmission. There is a head of water of 3·8 metres (12·5 feet), and the turbines make 30 revolutions per minute, the dynamo 150 revolutions. The latter is geared with the turbine, and from the machine the conductors lead, in the first instance, to a switch-board provided in the usual manner with measuring instruments for electromotive force and current, with lead safety fuses, and relays making contact with an automatic switch. The latter enters into operation when the line is injured, thus cutting out the generator in case of accident. A continuous-current dynamo of the Allgemeine Elektricitäts Gesellschaft, driven by a special turbine, serves as exciter for the generator and supplies its current to the latter by means of two brass-wire ropes. A regulating resistance and an automatic speed regulator, constructed by Messrs. Voith, of Heidenheim, and an Oerlikon transformer complete the plant in the turbine house. From the switch-board the current passes to the transformer just mentioned, and is there converted into a current of high pressure and small strength. It has been found that the air is not a sufficient insulator for currents of very high pressure, and the transformers have, therefore, been placed in vessels filled with oil. The transformers have a capacity of 200 kilowatts, and the converted current starting from Lauffen has an electromotive force of 25,000 volts at about 12 to 13 amperes. The current is conveyed from the generator to the transformers by stout cables of 27 mm. diameter. There are altogether three transformers installed at Lauffen, one for use and the two others for reserve.

"For transmission of the converted high-pressure current three thin bare copper wires of no more than 4 mm. diameter are sufficient. These line wires are erected in the same way as ordinary telegraph lines; the poles to which they are attached are 8 metres in height, and placed at distances of about 60 metres from one another; the number of poles employed amounting to about 3,000. The necessary copper wire, of about 530 kilometres length and 60,000 kilogrammes weight, has been lent by Messrs. F. A. Hesse and Sons, of Heddernheim, in the interest of this highly important experiment. The erection of the line was very much facilitated by the active support and co-operation of the Governments of Würtemberg, Baden, and Hesse, through whose territories the line had to be led The Allgemeine Elektricitäts Gesellschaft and the Oerliken Works have, in addition

to the above-named machines and apparatus, also supplied the very expensive oil insulators. These were manufactured after the type of the well-known Johnson and Phillips insulators, by Messrs Schomberg and Sons, of Berlin. They differ from the insulators commonly used in telegraph lines by being provided with one or more troughs filled with oil.* Porcelain itself is a very good insulator, even for high-pressure currents, but on the surface of the insulator moisture is condensed, which not only diminishes the insulating capacity very considerably, but also causes the formation of a coating of dust and dirt, which still further diminishes the insulation. For a few thousand volts, insulators the cup of which is bent inwards at the bottom, thus forming one trough, have proved thoroughly efficient, but for higher pressures three troughs are formed inside the insulator cup.

"The line projected by Mr. Ebers takes the following route:—Lauffen, Heilbronn, Jagstfeld, Eberbach, Erbach, Babenhausen, Hanau, and Frankfort. Between Lauffen and Eberbach, about one-third of the whole distance, the large insulators with three troughs have been used, but time being too short to manufacture the remaining 9,000 insulators after the same model, insulators of the smaller type, with one trough only, had to be employed.

"At the Frankfort Exhibition the high-pressure wires were led to three oil transformers like those in Lauffen. One of these, constructed by the Oerlikon Works, reduced the pressure to about 100 volts at a corresponding increase of current. This transformer was located on the left of the main entrance of the distribution hall. It furnished the current for feeding 1,200 glow-lamps, partly fixed to a large frame in the transformer room, partly to a sort of signboard outside the hall. The remainder of the current, corresponding to about 100-horse power, was reduced to the requisite electromotive force of 100 volts by two transformers of the Allgemeine Elektricitäts Gesellschaft. These two transformers were placed in a special shed on the right of the hall. The secondary currents furnished by them served for operating a large rotary-current motor of the Allgemeine Elektricitäts Gesellschaft, as well as some other smaller motors of the same company. The large motor made 600 revolutions per minute, and was coupled direct to a centrifugal pump, built by Messrs. Brodnitz and Seydel, of Berlin, which supplied a waterfall of 10 metres height on the right of the hall. Thus we see one portion of the electrically transmitted energy transcribe a perfect circle. A waterfall at Lauffen is the starting-point of the energy, and part of this latter is again brought before our eyes in the form of a waterfall at Frankfort.

"In view of the enormous pressures employed in the transmission (potentials of from 12,500 to 25,000 volts), the most elaborate precautions had to be taken, for currents of such high electro-motive force are absolutely fatal. The measures of precaution taken to prevent any accident are of such a kind that they appear to exclude any risk whatever, unless wilfully tampered with. The transformers in Lauffen as well as in Frankfort were placed in buildings inaccessible to the public during working hours, and the lines have been led along the railway tracks to remove them from interference on the part of the public. Both at Lauffen and at Frankfort they have been protected against lightning effects, and at both termini, as well as at

* *See* page 39.

certain intermediary stations, efficient safety contrivances have been constructed Finally, there are at both end stations measuring instruments which immediately indicate any irregularity in working, and, if needs be, automatically interrupt the current. These safety contrivances were, on September 2, tested by Würtemburg Government officials in Lauffen, and disturbances such as might occur on the line by the entanglement, the falling down, or breaking of wires were purposely brought about. By the entanglement of the lines and the short-circuit caused thereby, the safety cut-outs in the machine-room were immediately melted and interrupted the current ; one or more broken wires immediately actuated the current relays mentioned above and the automatic switches, cutting the machine out of circuit. On placing the wires on the rails of the railway line, the relays and switches again were set in operation with the same effect." *

The success of this great experiment, which is the most important that has been made in technical electricity, inaugurates a new era for the electrical transmission of power, which, however, really dates from the original researches of Marcel Deprez, which were put into actual practice at the Munich Electrical Exhibition in 1882, when the transmission of energy between Munich and Miesbach, a distance of about 60 kilometres (37 miles), was successfully accomplished. The pressure used was 2,000 volts, and no conversion of current was made, and no special precautions were taken as regards the insulation of the line, whereas in Lauffen-Frankfort the current generated is one of low electromotive force and great strength, which is in the first instance converted into one of high electromotive force and small strength, and thus conveyed to the place of consumption.

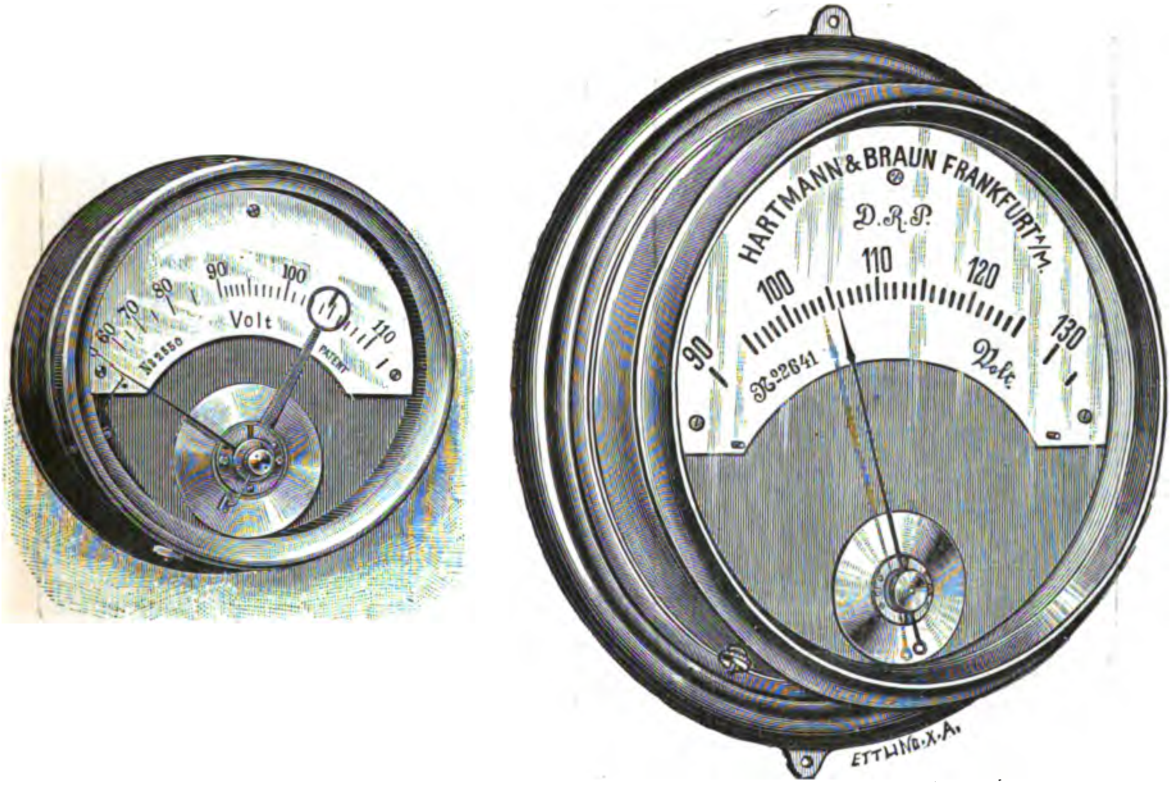
This arrangement allows, first of all, the employment of a generator of the simplest possible construction, with a transformation involving a very slight loss indeed, amounting to less than five per cent., and, secondly, the converted current requires for transmission a wire of very small diameter (only 4 mm.), and thus renders the transmission practicable from an economical point of view. And, thirdly, the use of oil insulators, both for the transformers and for the line wires, reduces the losses very considerably, so that the report of the jury of experts under Professor Weber, shows that of the 113 H.P. taken out of the river, the amount received 110 miles away at Frankfort was 81 H.P. ; an efficiency, in spite of all possible sources of loss of 72⅛ per cent. In the case of the Miesbach-Munchen transmission these losses exceeded 50 per cent.

* From Dr. J. Maier's account in the *Times*, September, 1891.

MEASURING INSTRUMENTS.

BY HARTMANN & BRAUN, FRANKFORT.

A by no means unimportant part of the equipment of electric light stations is that of the measuring and testing apparatus. In the following pages illustrations are given of a number of instruments made by Hartmann & Braun, and specially designed for commercial use. The principle employed in many of these is the simple one of using coils to suck in soft iron cores, the motion being opposed by springs. Fig. 117 shows



FIGS. 117 & 118.—VOLTMETERS.

a voltmeter constructed in a different way. A horizontal coil has a core made up of three parts; when a current passes through the coil, the parts tend to set themselves in a line, thus moving the index, gravity being in this case the controlling force. Fig. 118 shows a voltmeter, on the same principle, the diameter of which is no less than 20 inches, so that the scale, which is very open, can be easily read 50 feet away, across an ordinary engine room.

Fig. 119 is a signal voltmeter of the solenoid type. If the voltage varies between certain limits the horizontal wire seen in the figure makes a contact and brings a relay into action, which rings a bell and lights one of the two lamps above, red or green, according as the maximum or minimum voltage has been reached.

The method of working the registering ammeter and voltmeter, Fig. 120, is obvious from the illustration. Fig. 121 shows an ammeter on the same principle as the signal voltmeter. Fig. 122 illustrates one form of supply meter made by Hartmann & Braun. The solenoid, S, has a core so designed as to make the reading

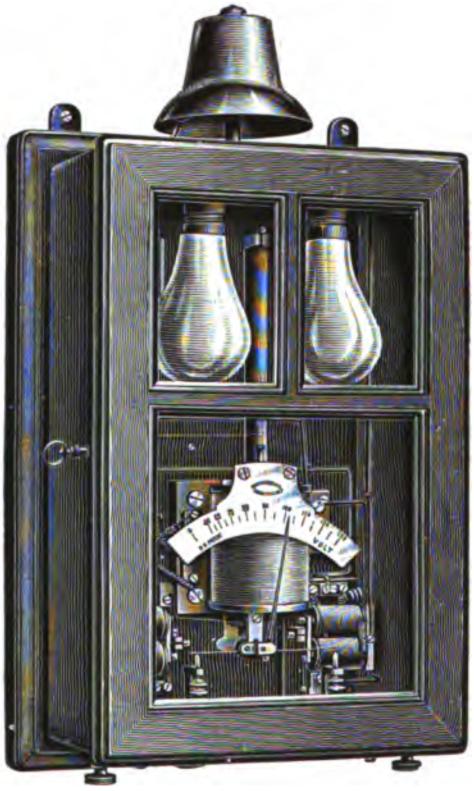


FIG. 119.—SIGNAL VOLTMETER.

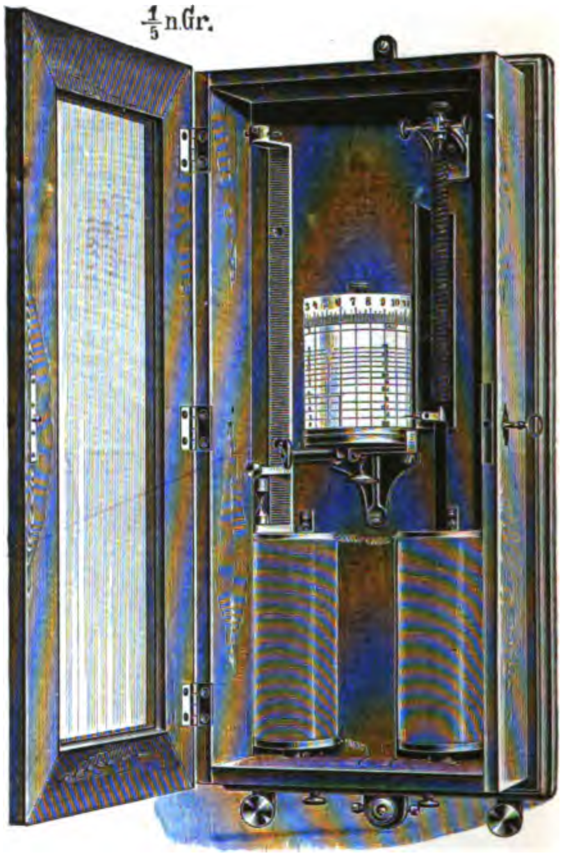


FIG. 120.—REGISTERING AMMETER AND VOLTMETER.

proportional to the current. The index is brought back to zero at short intervals by the Z-shaped electro-magnet, M; this movement is also communicated to the hands of the clock faces. The magnet, M, is controlled by a small self-winding clock, U, which is kept going electrically.

Fig. 123 illustrates a form of direct reading galvanometer, in which the needle is in the shape of a ring, the poles being in the centres of two coils. The wattmeter, Fig. 124, has a coil instead of a permanent magnet; this has the advantage that the constant of the instrument does not change, as may be the case with a magnet. A small

voltmeter intended for testing the condition of single accumulator cells is illustrated by Fig. 125.

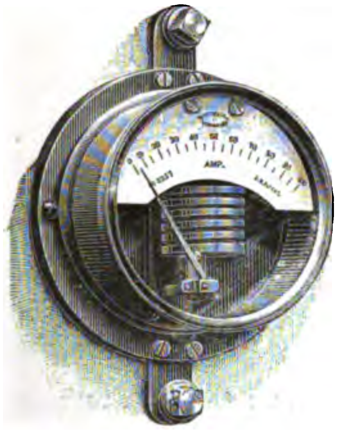


FIG. 121.—AMMETER.

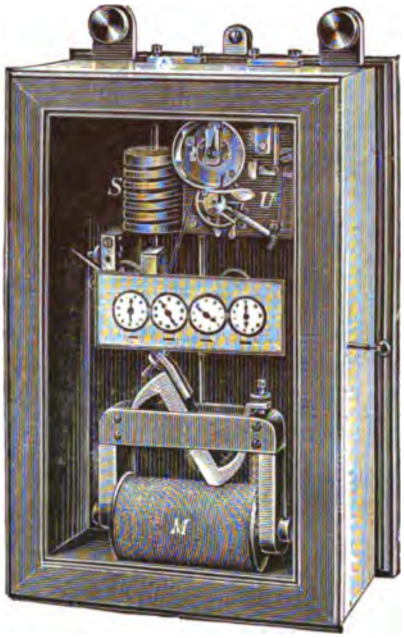


FIG. 122.—SUPPLY METER.

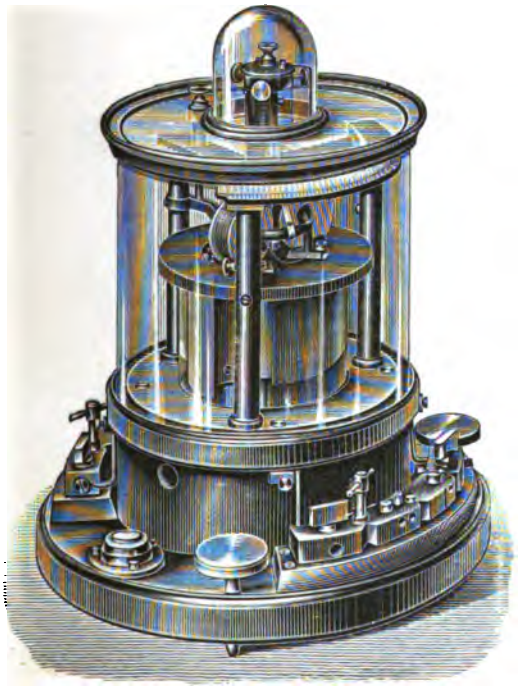


FIG. 123.—DIRECT READING GALVANOMETER.

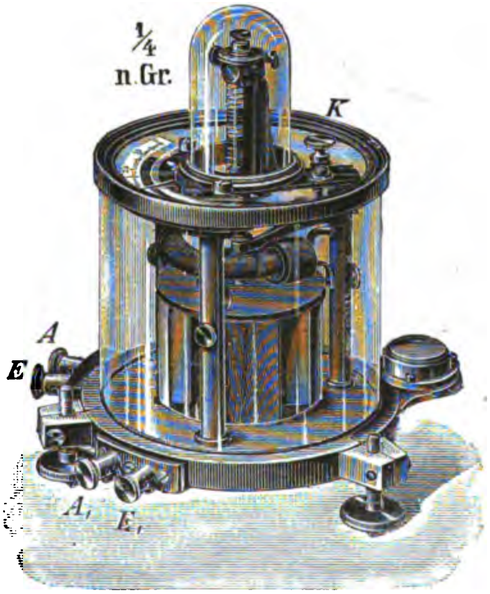


FIG. 124.—WATTMETER.

The silver voltameter, Fig. 126, is used for chemically measuring a current when

great accuracy is required, as in instrument calibrating. Fig. 127 shows a Wheatstone

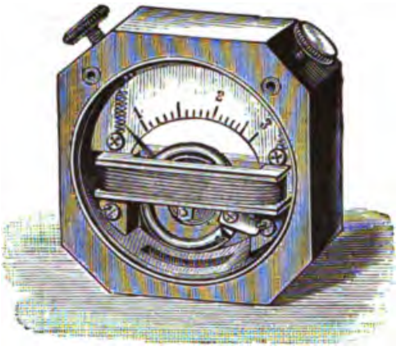


FIG. 125.—VOLTMETER FOR ACCUMULATOR CELLS.

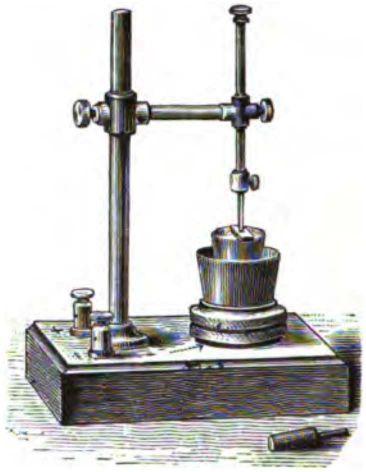


FIG. 126.—SILVER VOLTAMETER.

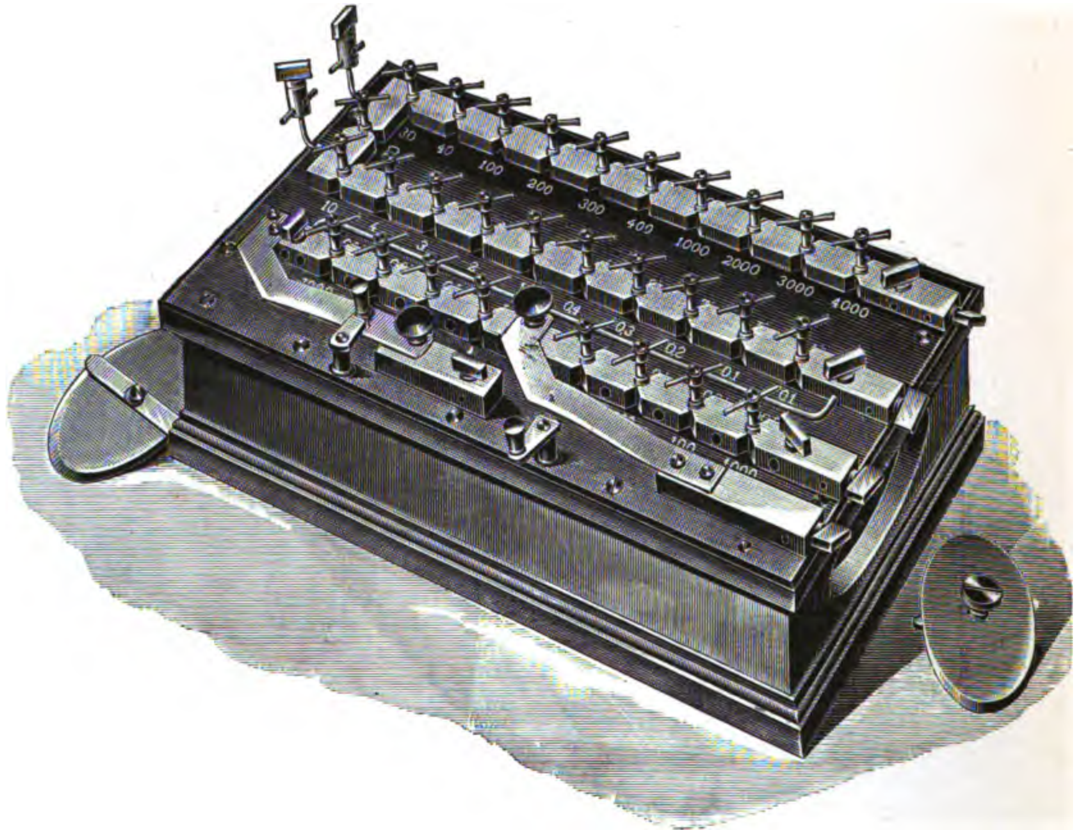


FIG. 127.—WHEATSTONE BRIDGE.

bridge suitable for measuring resistances of a few hundred ohms up to a megohm. A mirror galvanometer to use with this is shown in Fig. 128; this instrument has a

telescope and scale mounted on a balanced arm, being thus complete in itself, and not requiring a separate scale and lamp ; the advantage is that a dark room is not needed, but it has the objection that the observer must place his eye at the telescope. For small resistances, such as short lengths of wire, a bridge of the form shown in Fig. 129 is used.

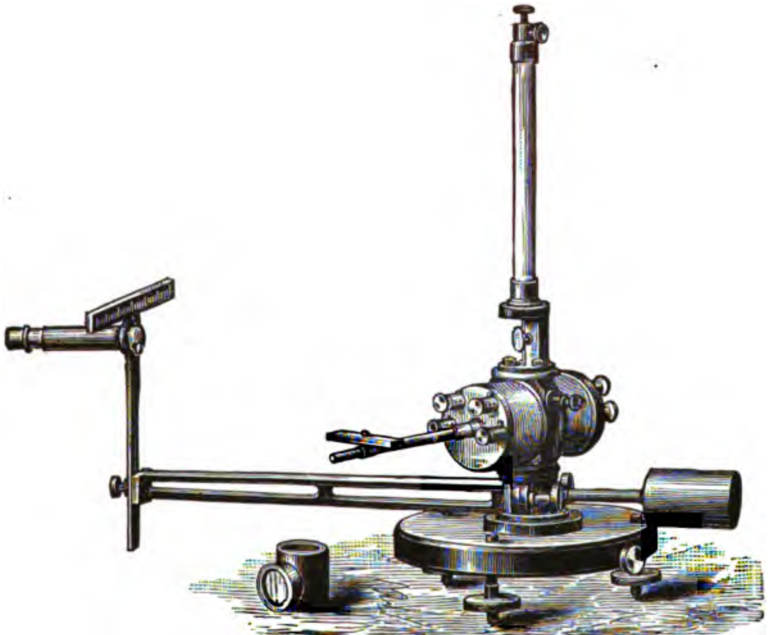


FIG. 128.—PORTABLE MIRROR GALVANOMETER.

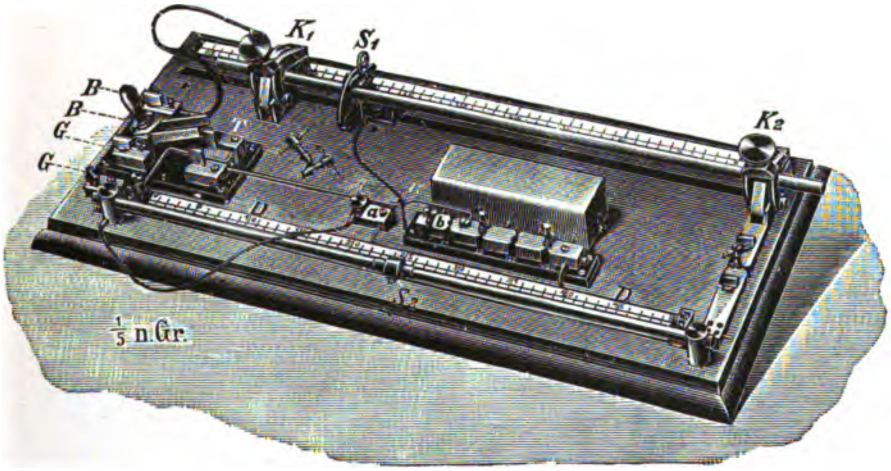


FIG. 129.—BRIDGE FOR SMALL RESISTANCES.

A very important point in connection with the distribution of electrical energy is the insulation resistance of the system ; galvanometers suitable for measuring this are illustrated in Figs. 130 and 131 ; for ascertaining the constant of these instruments, a variable resistance up to one megohm is used ; the galvanometers are provided

with shunts to increase their range of usefulness. For measuring insulation resistances

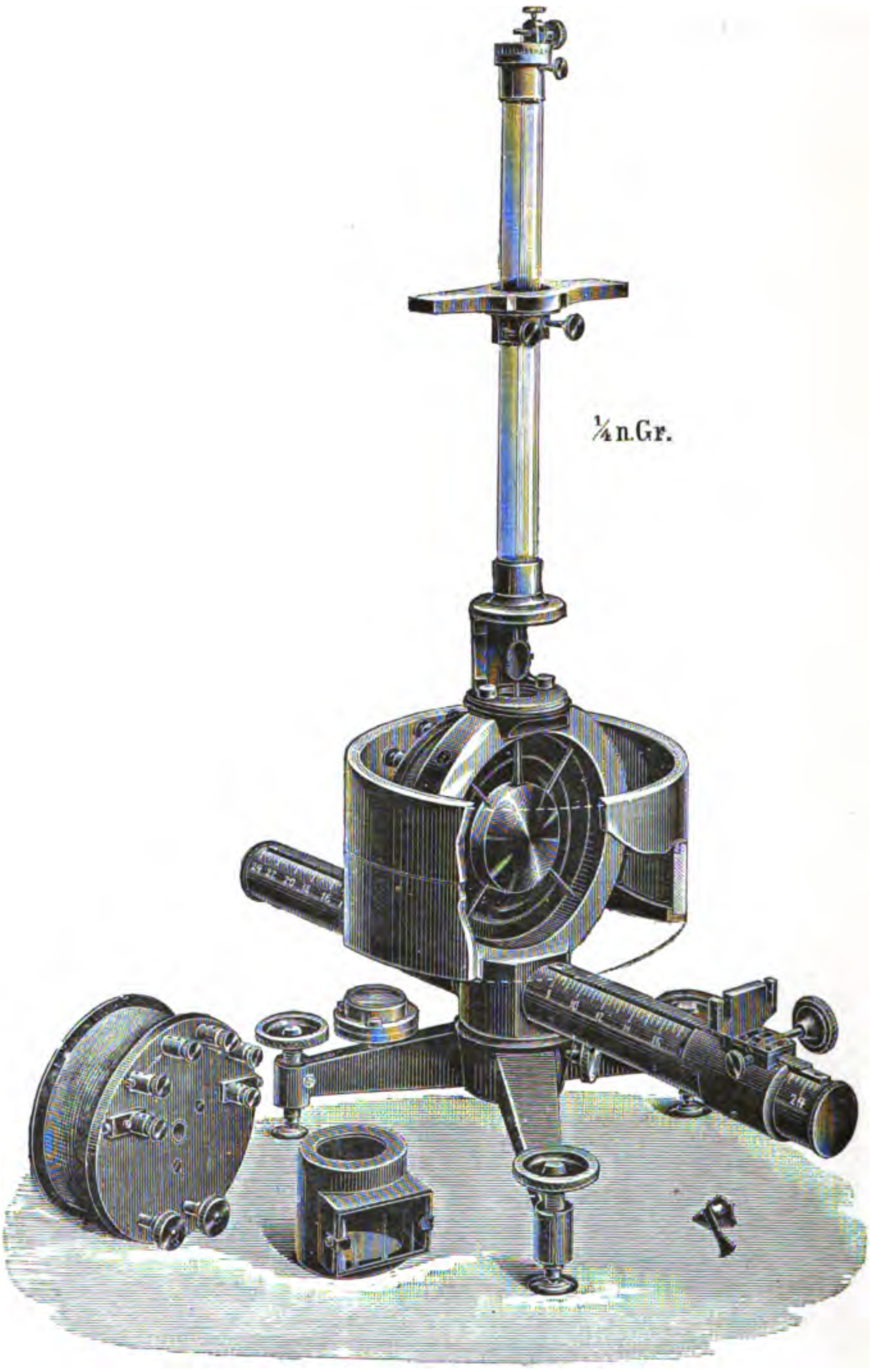


FIG. 130.—MIRROR GALVANOMETER.

it is obvious that the instruments used must be themselves well insulated; Fig. 131 is shown on vulcanite supports provided for this purpose.

Fig. 132 shows a portable set for testing insulation. This is a convenient piece of apparatus containing dry cells to give about 100 volts, with a very sensitive galvano-

FIG. 131.—ASTATIC MIRROR GALVANOMETER.

meter and a standard resistance; measurements can be made of from 1000 ohms up to 10 megohms. For rough measurements, where it is only required to know that the resistance is above a certain amount, one of the simpler forms of instruments shown in Fig. 133 is employed; the current generated by the magnets does not ring the bell unless the resistance being measured is below a certain amount. In the other form shown a galvanometer takes the place of the bell.

A set of apparatus is illustrated in Fig. 134 for testing the condition of lightning

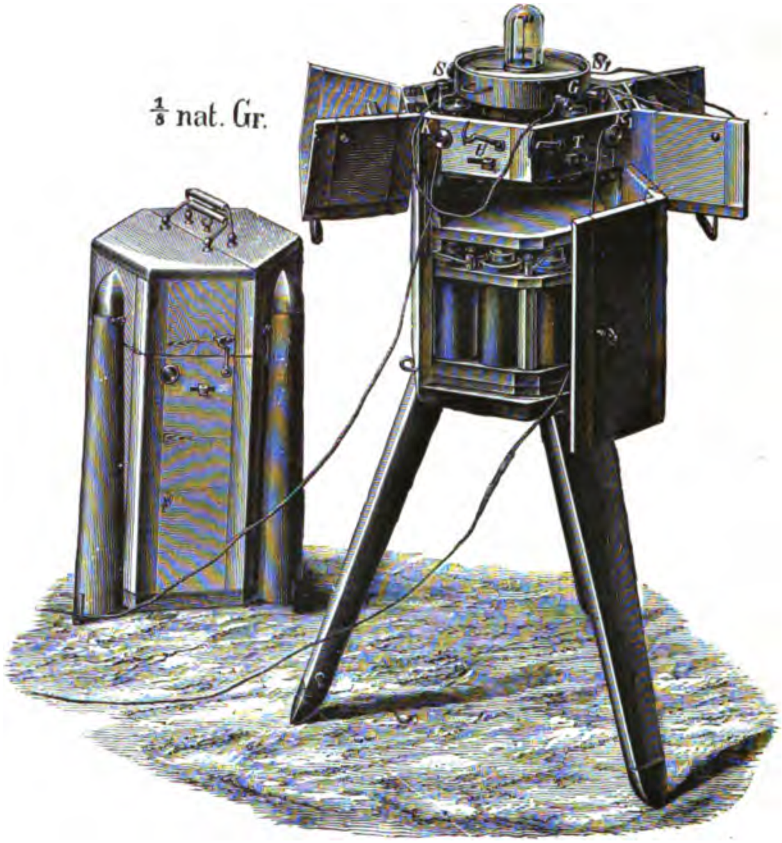


FIG. 132.—PORTABLE TESTING SET.

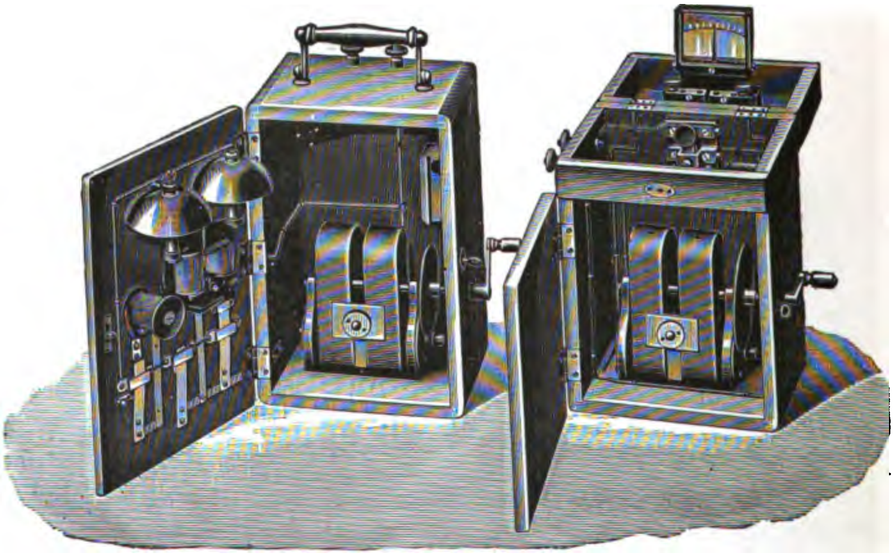


FIG. 133.—LINESMAN'S TESTING SET.

conductors. Fig. 135 shows another form of bridge in which a telephone with an electromagnetic interruptor takes the place of a galvanometer.

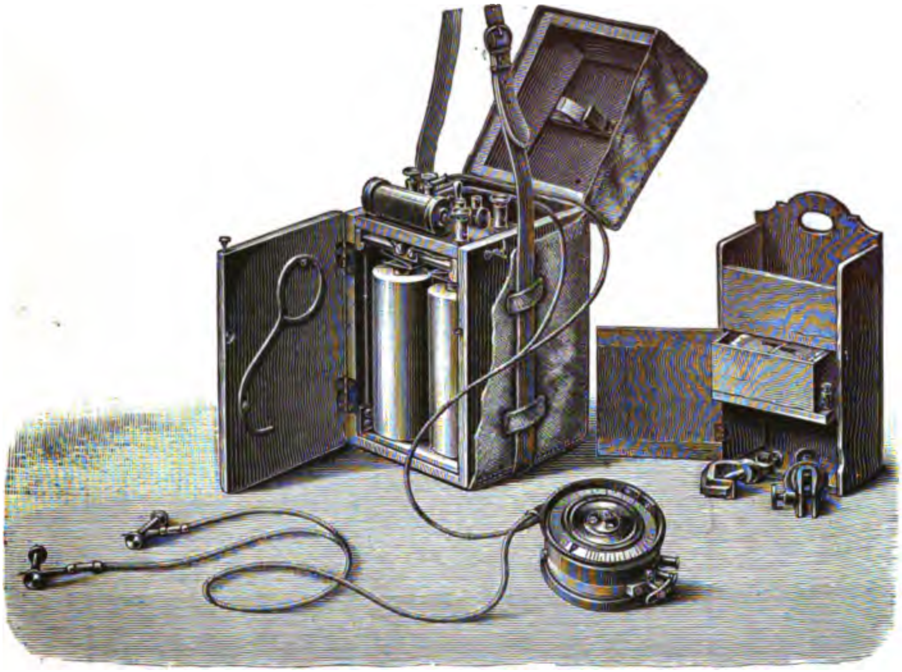


FIG. 134.—TESTING APPARATUS FOR LIGHTNING CONDUCTORS.

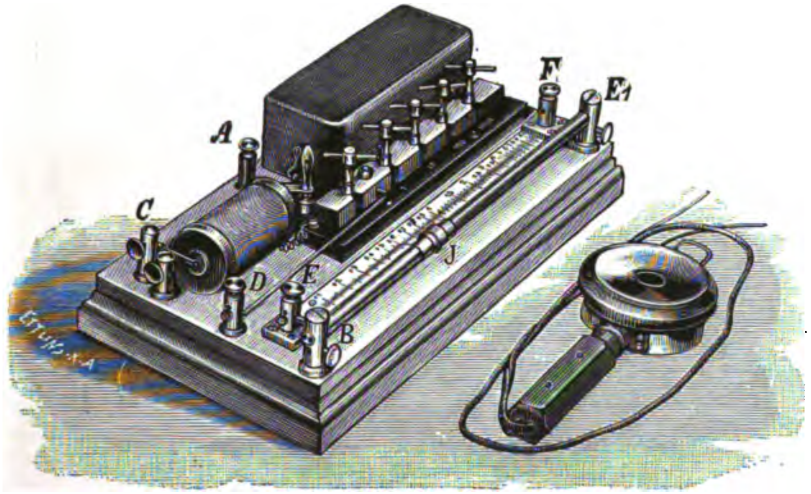


FIG. 135.—MEASURING BRIDGE WITH TELEPHONE.

A great deal of useful information with regard to the proper utilisation of fuel in the furnace can be obtained by the use of the pyrometer. A platinum wire is fastened in an iron or platinum tube, Fig. 136 (one-tenth natural size), and its resistance, depend-

ing on its temperature, is measured with a magneto and telephone or galvanometer, Figs. 137 and 138, the instruments being direct reading in degrees of temperature.

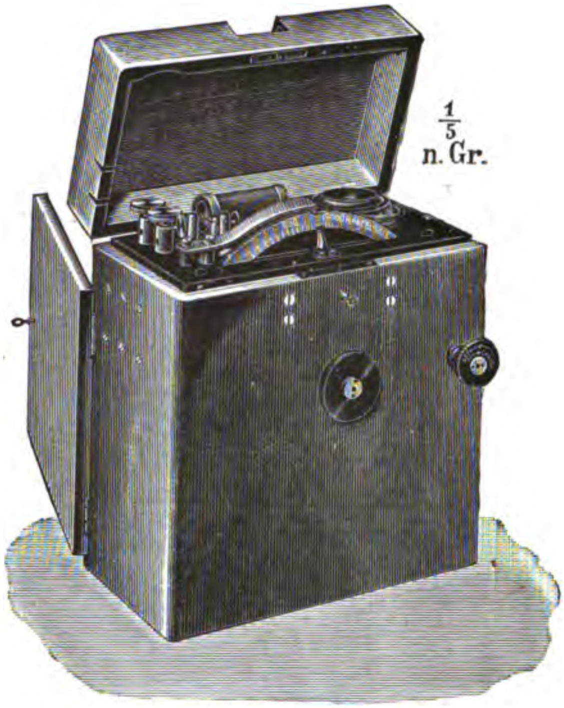


FIG. 137.

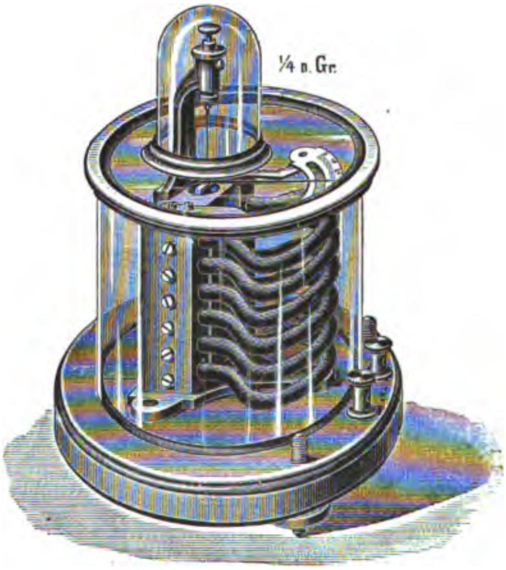


FIG. 138.

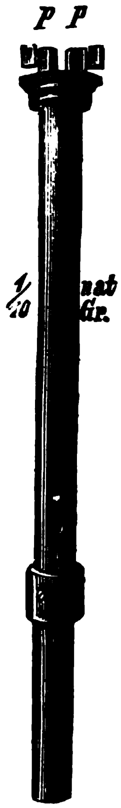


FIG. 136.

Messrs. Hartmann & Braun's exhibits were shown in a pavilion by themselves at the Frankfort Exhibition, and seemed to admirably fill the want which has been often expressed for commercial electrical measuring instruments.

CONDUITS FOR ELECTRIC MAINS.

Messrs. Crompton & Co., of London and Chelmsford, are the pioneers of this system, having already laid over thirty miles in London alone.* The arrangement may be described in a few words as the employment of a naked copper conductor, stretched on porcelain or glass insulators, which are built into a concrete trench cut preferably under the pavement. Fig. 139 is taken from a photograph of the conduit, which is ready for the insulators; although the illustration shows work in progress for

FIG. 139.

the Notting Hill Company, the standard dimensions of conduit employed here are also being largely used on the Continent, notably among other installations for the town of Perpignan in France, where several miles of naked conductors are laid in the English fashion.

* See the "Electrical Engineer," Vol. VII., pp. 8, 41, 71, and 86.

Another well-known form of conduit* is that of the Callender Webber system The material employed is a bitumen concrete, the conduit being laid in short slabs

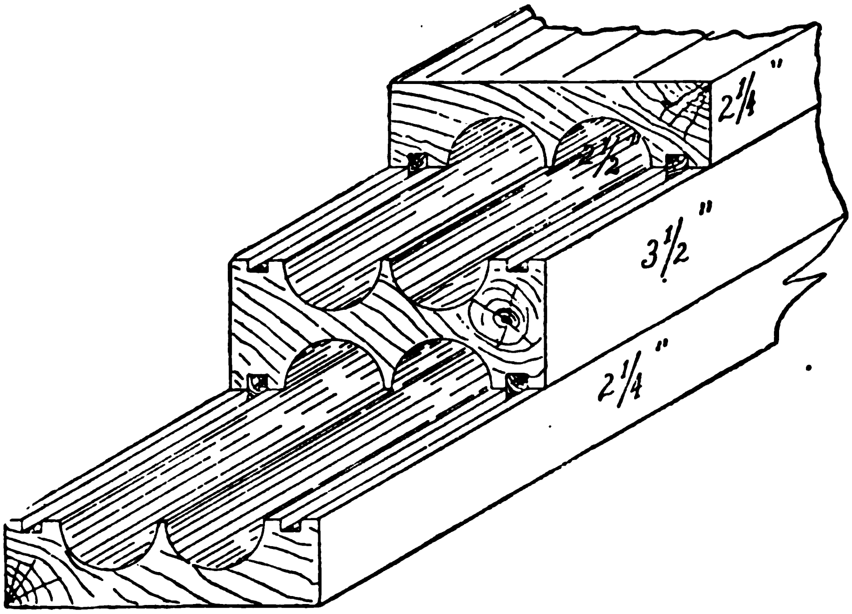


FIG. 140.—THE MACDONALD SUBWAY CONDUIT.

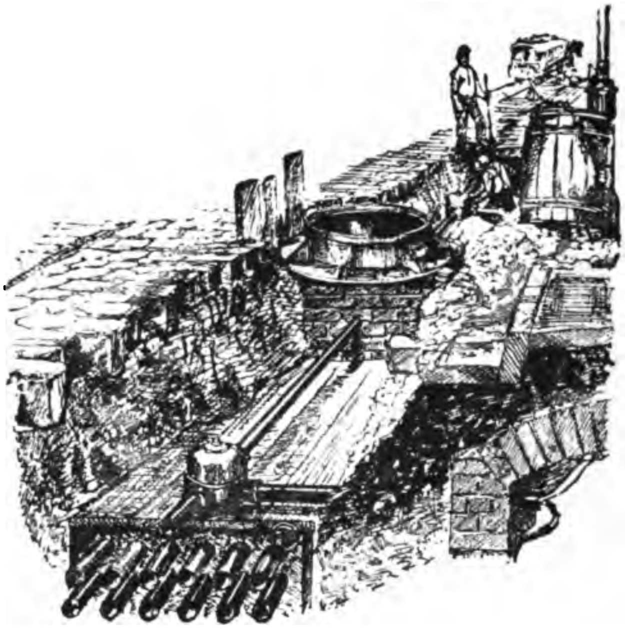


FIG. 141.—ELECTRIC CONDUIT IN CONSTRUCTION.

perforated with holes through which the cables are drawn. The system is exclusively adopted for the towns of Odense, Denmark, and Le Mans, France.

* See the "Electrical Engineer," January and February, 1891.

The Macdonald conduit (Fig. 140) is very largely used in the United States. It differs from the Callender Webber in that it is constructed of creosoted wood, and is made in halves, so that the joints instead of simply butting together form a bond which facilitates the connection of each length, and renders the joint perfectly water-tight. Messrs. Spencer & Co. are manufacturing this conduit at their Mile End Works.

Since underground cables have been rendered compulsory in New York and many American cities, conduits of various types have been employed. One of the most ordinary designs is constructed of wrought-iron pipes two-and-a-half inches inside diameter, lined with cement, and laid in hydraulic cement concrete, the whole being cased in with creosoted planks. Fig. 141 shows the conduit in course of construction, with manhole opening from which the house service is taken by means of the junction-box through the vault on the right into the house. Fig. 142 is a section through the manhole, the arc lighting service going up the lamp-post, and a branch to the bracket, which is fixed to the wall of the house.

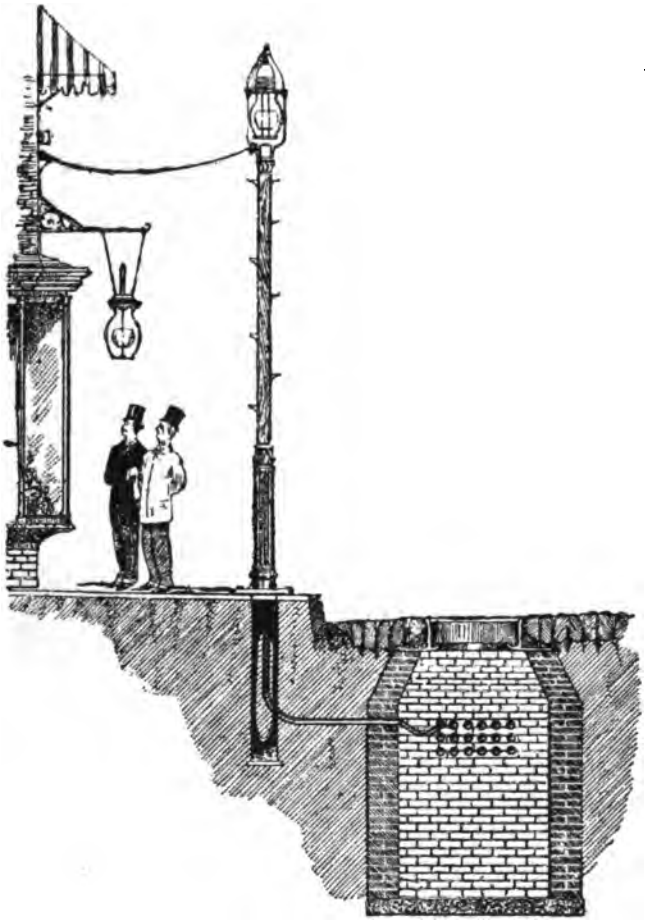


FIG. 142.—SECTION OF CONDUIT, WITH ARC LAMP CONNECTIONS.

ON THE DISTRIBUTION OF ELECTRICITY COMPARED WITH GAS.

If the electric light is to compete in a satisfactory manner with gas, a constant service is absolutely necessary; this is an important matter, and one that governs the first cost of an electric light central-station. Electricity cannot be stored in gasometers like gas; but, on the other hand, a constant pressure can be economically maintained throughout the district, either by the use of the secondary battery, which is often wrongly termed an accumulator, or by means of small dynamos worked by steam or gas-engines.

In this matter electricity is ahead of gas, in that the latter is always in the pipes, and consequently ready to escape at any minute leak, while the former does not exist in the mains until the circuit is closed. Of course there will be a loss, but while with a system of properly designed electric mains this loss is a known constant, with even the very best distribution by gas, the loss is an unknown quantity, which in London must be very great, as one sees the soil blackened round the gas mains, and it is almost impossible to grow trees in the immediate neighbourhood. The losses with both illuminants are, to a certain extent, proportional to the consumption. When there is a great demand for gas a greater pressure is required to force it through the mains; and with electricity more power has to be given off by the generators. In order to successfully plan a system of distribution from a central electric light station, it is not sufficient to know the number of lamps which are to be maintained, but it is necessary to have almost an exact idea of the consumption in each district, so as to show the fluctuations in the twenty-four hours at different periods of the year.

The diagram, Fig. 143, has been so arranged that the amount of light required in a given district can be ascertained for any period of the day or night; it has been calculated from the observations taken daily at one of the Berlin central-stations by the engineer to the company.

Fig. 143 has two vertical scales, A and B, each giving the kilowatts and corresponding horse-power. A is drawn to a scale ten times greater than B, with the object of noting the smaller amount of lights required for street illumination. The horizontal line is divided into hours, and represents a day's lighting in the middle of December and the end of July, so as to show the maximum and minimum amount of current that will be required. In the lighting of a town there are two classes of illumination, the amount taken by the public, which is uncertain, and that employed for street lighting, which is a known quantity.

The curves, 11 and 11A, represent the private lighting of houses, hotels, theatres, and shops of different kinds in December and July, the curve, 11A, being in dotted lines clearly shows what a vast difference there is in the amount of light, and con-

sequently in the amount of energy required in the generating station, as compared with curve II, which is taken when the days are shortest.

The rectangles, I and IA, show the street illumination, and are drawn to suit scale A ; half an hour after sunset all the lamps are turned on, and the work reaches its maximum suddenly, and continues the same until 12 o'clock, when, according to the municipal decrees, it either falls one or two gradations until half an hour before sunrise, when all the lamps are extinguished. The calculations are based on the assumption of 640 watts to the horse-power, instead of 736, which is the theoretical equivalent of a German horse-power.

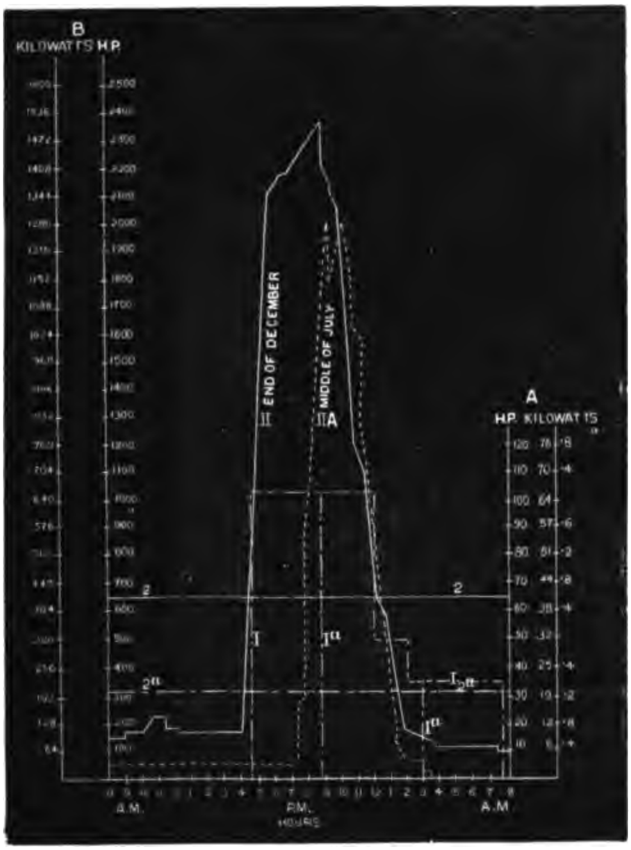


FIG. 143.—DIAGRAM SHOWING VARIATIONS OF LOAD.

The lines, 2 and 2A, show the constant work at the same two periods of the year from which the diagrams are taken. The constant work at the end of December will be found to amount to 20 per cent. of the total work, and that at the middle of June to 15 per cent. By summing up the average work for all the days in the year we obtain the cost per annum, and adding to this the expense of management, interest, etc., and knowing the local conditions, we can fix what proportion of the day's work is admissible as loss. With the Edison system at Berlin, 5 per cent. is taken as average loss ; thus, at the end of December, it amounts, with the

maximum number of lights, to 18·8 per cent., and with the minimum to 1·1 per cent.; in the middle of July the maximum is 15·8 per cent., and the minimum 0·5 per cent. The dynamos must, of course, be of sufficient power to be able to overcome this loss, which only shows itself periodically; therefore the machine may be constructed to give, nominally, 20 to 30 per cent. less than the maximum work, and be capable of being pushed to the full amount for a short time only.

The following diagrams, Plate XXV., were compiled by Professor Forbes from statistics prepared by the Berlin Central Station. They show the interest on plant, the depreciation, cost of management, and the cost of maintenance, labour, coal, and fuel. From these diagrams it appears that the maintenance is almost in direct proportion to the energy supplied at all periods of the year, whether it was a light or a heavy load. The cost of a unit of electrical energy in June and November, the months of minimum and maximum output would be in the ratio of 37 to 86, but the difference in the cost of the unit sold was due almost entirely to the permanent charges, management, depreciation, and interest. If a number of diagrams are taken on this method for different periods of the year, the constant work can be ascertained. This knowledge is most valuable when calculating the most economical area for the mains, which is then easily accomplished by means of Forbes' tables, which are based on Sir William Thomson's well-known rule.

LOAD-FACTOR.*

The practical use of the load diagrams is to ascertain what has been defined by Mr. R. E. Crompton as the "load-factor" of the station, namely, "the relation which the area of all the load diagrams of a week, month, or any given period, bears to the area of the rectangle contained between the base line on which these load curves are drawn, and a line drawn parallel to it through the highest point of maximum load observed at any time during the year." The time during which the greatest amount of lighting is required in summer may be only two hours out of the twenty-four, and even in winter, during the shortest days, it may only extend to eight hours out of the twenty-four. In order to show the extent to which these conditions of partial loading affect the cost of electrical energy, the name of load-factor has been given to the relation which the actual output of a plant of any given size bears to what would be its output if it were worked continuously day and night at the full load for the same period. For instance, if in a lighting-station the output of the plant working continuously day and night the full power for the month of November may be taken at 100 units, whereas it is found that the actual output is 16·6 units, then it would be said that the load-factor for that station for the month of November was 16·6 per cent. In the summer months at the same station it may perhaps fall as low as 5 per cent.

* Crompton on Electrical Energy, Minutes Institution Civil Engineers, Vol. CVI.

NETWORK OF MAINS.

The plan which is now adopted when a supply of electricity has to be distributed over a given area is to form a network, with the view of keeping the pressure equalised at various points. If the mains were very long and arranged in ordinary parallel circuit, those near to the dynamos would be exhausting the supply and the lamps at the remote end would not get the full pressure. A system of feeders has therefore been devised so that each lamp, no matter where it may be, shall have approximately the full 100 volts working through it. In Fig. 144 a series of feeders *ff'* are taken from the dynamo mains and fed direct into the branch mains at various

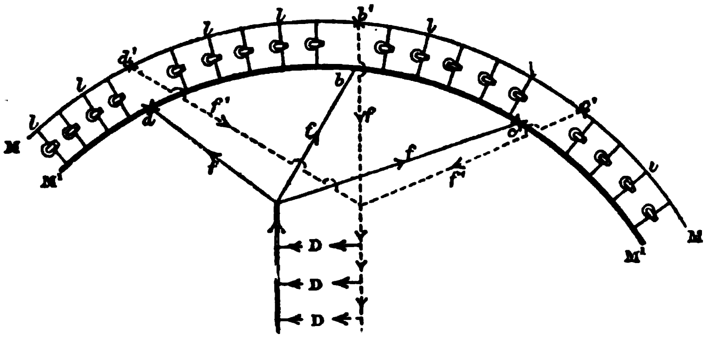


FIG. 144.—PARALLEL SYSTEM WITH FEEDERS.

points *dd'*, *bb'*, *cc'*, in order to equalise the electrical pressure. A recent example on the three-wire system is that at Notting Hill, London, and on a still larger scale at Berlin; the three conductors laid throughout the district form the network, those of equal potential or pressure being coupled together at all the intersection points. This network is supplied with electrical energy by a number of feeder mains, which run from the generating station alongside the main cables up to various chosen points. Potential wires are carried back from these points to the station, so that the pressure can be observed on suitable voltmeters and maintained constant by the engineer in charge.

THE INTERESTS OF GAS COMPANIES WITH REGARD TO ELECTRIC LIGHTING.

The account of the electric light installation at Dessau, which has been carried out by the Continental Gas Company, who furnish the gas supply for the town, is especially interesting to those interested in gas works. The success of the installation strengthens the view which was put forward by the writer some

years ago,* that in towns where no provisional order had been obtained for electric lighting, or where the order had lapsed through the undertakers having failed to carry out the statutory requirements, the most suitable organization for introducing a system of electrical distribution would be one promoted in connection with the existing gas company. It is true that an order would not probably be granted to a company undertaking the supply of gas, but a new company might be formed to be worked under the same direction, and consequently in harmony with the owners of the gas monopoly. In England the policy of gas companies with regard to the electric light has been, with few exceptions, such as the municipal authorities of Manchester and Bradford, who own the gasworks, a state of indifference to the progress of things electric, with contempt for a rival whose opposition is not sufficiently powerful to be appreciated. The chairman of a well-known gas company stated, what is undisputed—that the introduction of electric arc lights was accompanied by an increased consumption of gas in the immediate neighbourhood where these lights are used; but it is very doubtful whether this will be the case when incandescent lights are generally supplied. The introduction of these lights into any business district would mean the displacement of at least as many burners as there are electric lamps; and this reduction not only means loss of income, but also loss by interest on plant which is not kept at work to the capacity for which it was designed. The question suggests itself: Are existing gas companies more favourably situated for furnishing electricity than any one else? There are many reasons in favour of the supposition that the directors of gas companies have, at the present time, an opportunity of acquiring almost as complete a monopoly of lighting by electricity as they have with gas. As regards central-stations, everything is in their favour; there is generally some spare ground for the machinery, waste heat could be utilised, and a cheap fuel in the shape of coke is ready to hand. They have greater facilities for breaking up streets without danger of troubles arising with the local authorities, and if the Gasworks Clauses Acts, which authorise their existence, tie them down to one illuminant, a very little expenditure would enable them to enlarge their powers. In many towns the shareholders are local men who wish to use the electric light, but cannot favour its introduction because they think it would tend to smaller dividends or lower quotations for their shares; if, however, a scheme was promoted either by the gas company, or, if that was impossible, if the directors interested themselves in a separate electric-light undertaking, the security which the gas and water investments command would, no doubt, cause a sufficient number of local subscribers to come forward and make even a small installation a paying concern. The Imperial Continental Gas Association have already taken up the supply of electricity in a district of Vienna for some years; also in the United States the growing opposition of the electric light companies has been seriously discussed, with the result that there are now a very large number of gas companies who also distribute electricity. It is hardly in the province of this work to discuss the

* See page 96. "Central Station Electric Lighting" (Hedges).

value of gas shares, but with regard to the effect of electric light on the consumption of gas, the following extract from Mr. George Trewby's address to the Incorporated Institute of Gas Engineers, 1891, may not be out of place:—

"In 1880, the quantity of coal carbonized by the three London companies was 1,918,233 tons; the gas sold was 18,271,563,000 cubic feet; the number of private consumers was 263,922. In the period of ten years I find that the above figures have increased as follows:—Coal carbonized, 2,801,557 tons, an increase of 46·05 per cent.; gas sold, 26,433,573,000 cubic feet, or an increase of 44·67 per cent.; the number of consumers being 309,541, or 17·29 per cent. increase on the relative cost of gas and electricity for motive power." Mr. Trewby states that according to Mr. Crompton, "The cost of generating an electrical unit equal to 1⅓ horse power is given in two typical cases as respectively 1·41*d.* and 1·08*d.* when the conditions as to supply were the most favourable. This is for coal, labour, and petty stores. This is equal to 1·06*d.* and 0·8*d.* per horse power. Now, these same items in the cost of London gas do not average more than 10*d.* per thousand cubic feet; and allowing a maximum of 25 feet as necessary to the production of 1-horse power in a gas engine, the cost is 0·24*d.* or less than a third of the minimum electrical estimate. Or, if we take the cost of gas, as delivered to the consumer in London, at 2*s.* 9*d.* per thousand cubic feet, the cost of 1-horse power to the user is 0·83*d.*, which is very much less than the cost of materials and labour in generating the electricity, leaving distribution, loss, wear and tear, and dividends unconsidered. So that, however anxious electric-light companies may be to promote the use of electricity for power purposes, they will have to cheapen the cost to an enormous extent before they can compete with gas, considering that the larger size of gas engines (as I am informed by the makers) are now made to develop 1-horse power with only 16 cubic feet of gas."

This increase of consumption appears to be general according to the voluminous return on the gas undertakings of the United Kingdom, which is brought up to the 31st of March last, and states that upwards of 61⅓ millions are now invested in gas. Up to the date of this return, the gas undertakings show no signs of contraction consequent on the introduction of the electric light; the amount of gas sold maintains a regular rate of increase, both in the case of private companies and local authorities. Is there any reason why the gas companies should cease to grow in prosperity. Not the least! Ten years ago gas for heating purposes, for cooking, as a motive power, was almost unknown. What strides it has made in the meantime! It is certain that in the future the profits of the gas companies from these sources will more than counterbalance the losses from their decrease of custom for lighting. There are gasworks lighted by electricity; there are electric lighting installations worked by gas engines; there are companies that deal indiscriminately in gas and in electricity for the purposes of lighting. Here, in fact, are twin enterprises that never should be rivals.

CONTINENTAL CENTRAL STATION PRACTICE.

The principal difference between English methods and those adopted abroad for the generation of electrical energy is in the arrangement of the dynamos and their motors. The plan initiated at Berlin by Siemens and Halske may be termed the standard method, as it has been very largely copied. In this case the units of supply consist of slow-running steam engines of from 300 to 500 H.P., driving large slow-speed dynamos mounted direct on an extension of the crank shaft of the engine;* the generating plant probably occupies four times the space and costs twice as much as the quicker running steam dynamos of equal power used in English practice. The highly economical results of the Van der Kerchove engines used at Berlin have received just praise from Mr. Crompton and others in the discussion which took place at the Institution of Civil Engineers.† Although, perhaps, no higher economy can be obtained of water per electrical horse power delivered at the terminals of the dynamos than from the high-speed engines of Messrs. Willans, the durability of the slower type must tell in the long run. The units of plant used abroad are much larger than they are here—from 500 H.P. to even 1000 H.P., whereas in England for the same work we should have units of 200 to 300 H.P. each. In all probability the cause determining the size of the unit in England must be by reason of the fact that few districts for which provisional orders have been granted are likely to require more than from 2000 to 3000 H.P. to work them, and such an output can be very conveniently divided between eight or ten engines of 300 H.P. each. On the Continent, when the possessors of central stations are forced to increase their plant, they invariably prefer to incur the greater first cost of low-speed steam engines, even though the whole station might have been originally designed with a view to multiplying the existing high-speed machinery.

COST OF THE ELECTRIC LIGHT ABROAD.

The Continental electric light companies have considerable advantages from the money-making point over those in England. The hours of lighting are greater and are more evenly distributed throughout the year; consequently the "load factor" is much higher. This is due to the number of cafés and restaurants which remain open very late and in summer use the electric light in the open air portion as well, thus almost equalising the amount used with that during the winter months.

Special advantages are given to lengthened consumption, which will be seen by the

* For detailed descriptions see pages 114, 115.

† See "Crompton on Electrical Energy," Minutes Institution Civil Engineers, vol. cvi., page 17.

following tariffs, which are in use at Venice and at Cannes, and are selected from a number which have been collected from various towns.

Average number of lighting hours per month: Venice	0 to 40	41 to 80	81 to 125	126 to 150	151 and over
Per 16-candle lamp, per hour	8 centimes	7·30 centimes	6·70 centimes	6·10 centimes	5 centimes

100 centimes equals 9½*d.*

The average number of hours per month is calculated by dividing the total number of lamp hours registered by the number of lamps of 16 candles installed or their equivalent. A second method of charge is by having a fixed constant, which at Venice is the sum of £1 3*s.* 11½*d.* per 16-candle lamp; this is collected monthly at the rate of 3·50 centimes (a third of a penny) per hour, but the Company are entitled to demand the fixed amount at the expiration of a time which is first agreed on.

SLIDING SCALE: CANNES, FRANCE.

Per lamp from sunset to		9 P.M.	10 P.M.	Midnight.	2 A.M.	All night.
		Francs.	Francs.	Francs.	Francs.	Francs.
10-candle power.	For the whole year	48	63	87	108	132
	For the season, October 1st to May 15th	42	52·50	70·50	83	112
16-candle power.	For the whole year	78	102	144	174	204
	For the season, October 1st to May 15th	63	80·50	108·50	132	175

If the current is taken by meter, and the hecto-watt-hour = 100 watt-hours is taken for the unit and equals an ampere-hour under a pressure of 100 volts, the charge is fixed at 15 centimes the unit; but if 5000 hecto-watt-hours are used per month, the price is reduced to 14 centimes, similarly, for 10,000 units per month, to 13 centimes per hecto-watt-hour.

With nearly all the tariffs examined, lamps are supplied gratuitously by the company, and at both the towns mentioned the company replace those worn out, providing the glass is not broken or the fittings damaged. It is difficult to make comparison between the prices charged for electricity on the Continent and in this country; but as the price for gas is much dearer—probably on an average double that in England—an actual saving is made by taking a supply of electricity. Installation charges are much less on the Continent, and probably do not average more than 15*s.* 0*d.* per lamp against 35*s.* 0*d.* to 40*s.* 0*d.* in England. Greater facilities are also given by the Continental electric light companies, who, in order to secure the lighting of hotels, often instal the wires and fittings free of cost on an agreement being made that a supply of electricity shall be taken for a given number of years. The wires in large buildings are usually run on insulators in the manner shown by Fig. 13, page 15; this method is preferred to the use of wood casing, especially where the walls are damp; with good covered wire the insulator plan tests very well, the only objection is its unsightliness. With regard to the first cost of foreign central stations the figures given in the preceding pages show that the advantage is clearly in favour of English manufacturers, who, if the import duty was removed, could easily compete with

foreign electrical engineers. A visit to the recent Frankfort exhibition was quite sufficient to convince the most conservative Briton that all the electrical knowledge worth possessing is not within the limits of the United Kingdom, and that many useful lessons may be obtained in studying European practice, exemplified by the splendid stations of the Continent. Although to our ideas the switch-boards are often covered with an unnecessary number of complicated appliances, one must appreciate the forethought of a design which allows for human fallibility, and which was probably taken from the block signalling arrangements of railways, the connections being so arranged that without actual malice it is impossible to wrongly switch on the circuits.

RELATIVE COST OF ELECTRICITY AND GAS.

"THE 8 candle-power glow lamp is usually taken to replace a 5-ft. gas burner (at usual gas pressure), the light in each case being approximately equal. Again, an 8 candle-power lamp requires from 30 to 33 watt hours (that is ampere multiplied by volt hours), and as a Board of Trade unit equals 1000 amperes multiplied by volt hours, it consequently results that at 8*d.* per Board of Trade unit the cost comes out that thirty-three 8 candle-power lamps for one hour cost 8*d.* (if the value of the lamps be excluded). Thus: 1000-33 equals thirty-three lamps (8 candle-power) for one hour for 8*d.* Now glow lamps last over 1000 hours before renewal, say 1000 hours in this case, and each lamp costs 3*s.* 6*d.*, or 168 farthings; then the cost of wear of thirty-three lamps for one hour is 168-1000th, which multiplied by 33 equals 6 farthings, or 1½*d.* Consequently, the cost of one Board of Trade unit becomes 9½*d.* when wear of lamp is taken into account. One 8 candle-power lamp for one hour equals 9½*d.* divided by 33, which equals 1·15 farthing, or 1⅐ farthing. Gas being reckoned by price per 1000 cubic feet, a 5-ft. burner consumes 5-1000th or 1-200th of charged price per 1000 cubic feet. Consequently with gas at 2*s.* 6*d.** per 1000 cubic feet, a 5-ft. burner costs per hour 1-200th multiplied by 2*s.* 6*d.*, equals 120-200th farthing, which equal ⅗ or 0·6 farthing. Gas at 3*s.* per 1000 cubic feet, by a similar calculation, equals 0·7 farthing; gas at 3*s.* 6*d.* per 1000 cubic feet, similarly, 0·84 farthing; gas at 4*s.* 6*d.* per 1000 cubic feet also by same method, 1·08 farthing; gas at 5*s.*, one 5-ft. burner for one hour costs 1-200th multiplied by 5*s.*, equals 240-200 farthing, or 1·2 farthing. Consequently, the electric light, in point of cost, lies between gas at, per 1000 cubic feet, 4*s.* 6*d.* and 5*s.*, the actual value being over 4*s.* 10½*d.* and under 4*s.* 11¾*d.*"—*Sir David Salomons.* (*Nov.* 5*th.*, 1891.)

Edison-Swan incandescent lamps of 25 candle-power and under are recommended by the makers to be used at a voltage which gives an efficiency of 4 watts per candle;

* The Gas Light and Coke Company have since raised the price of gas.

for lamps above 25 candle-power, the power required for greatest efficiency is 3·5 watts per candle.

ELECTRICITY v. GAS.

Price per Board of Trade unit.	Equivalent price per 1000 cubic feet of gas (calculated on the assumption that a 16 c. p. gas burner takes 5 cubic feet per hour, the glow lamp being taken at various efficiencies of from $2\frac{1}{4}$ to 4 watts per candle-power).							
	WATTS.							
	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4
d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
2·4	1 5·3	1 7·2	1 9·1	1 11·0	2 1·0	2 2·9	2 4·8	2 6·7
2·7	1 7·4	1 9·6	1 11·8	2 1·9	2 4·1	2 6·2	2 8·4	2 10·6
3·0	1 9·6	2 0·0	2 2·4	2 4·8	2 7·2	2 9·6	3 0·0	3 2·4
3·3	1 11·8	2 2·4	2 5·1	2 7·7	2 10·3	3 1·0	3 3·6	3 6·2
3·6	2 1·9	2 4·8	2 7·7	2 10·6	3 1·4	3 4·3	3 7·2	3 10·1
3·9	2 4·0	2 7·2	2 10·3	3 1·4	3 4·6	3 7·7	3 10·8	4 1·9
4·2	2 6·2	2 9·6	3 1·0	3 4·3	3 7·7	3 11·0	4 2·4	4 5·8
4·5	2 8·4	3 0·0	3 3·6	3 7·2	3 10·8	4 2·4	4 6·0	4 9·6
4·8	2 10·6	3 2·4	3 6·2	3 10·1	4 1·9	4 5·8	4 9·6	5 1·4
5·1	3 0·7	3 4·8	3 8·9	4 1·0	4 5·0	4 9·1	5 1·2	5 5·3
5·4	3 2·9	3 7·2	3 11·5	4 3·8	4 8·2	5 0·5	5 4·8	5 9·1
5·7	3 5·0	3 9·6	4 2·2	4 6·7	4 11·3	5 3·8	5 8·4	6 1·0
6·0	3 7·2	4 0·0	4 4·8	4 9·6	5 2·4	5 7·2	6 0·0	6 4·8
6·3	3 9·4	4 2·4	4 7·4	5 0·5	5 5·5	5 10·6	6 3·6	6 8·6
6·6	3 11·5	4 4·8	4 10·1	5 3·4	5 8·6	6 1·9	6 7·2	7 0·5
6·9	4 1·7	4 7·2	5 0·7	5 6·2	5 11·8	6 5·3	6 10·8	7 4·3
7·2	4 3·8	4 9·6	5 3·4	5 9·1	6 2·9	6 8·6	7 2·4	7 8·2
7·5	4 6·0	5 0·0	5 6·0	6 0·0	6 6·0	7 0·0	7 6·0	8 0·0
7·8	4 8·2	5 2·4	5 8·6	6 2·9	6 9·1	7 3·4	7 9·6	8 3·8
8·1	4 10·3	5 4·8	5 11·3	6 5·8	7 0·2	7 6·7	8 1·2	8 7·7
8·4	5 0·5	5 7·2	6 1·9	6 8·6	7 3·4	7 10·1	8 4·8	8 11·5
8·7	5 2·6	5 9·6	6 4·6	6 11·5	7 6·5	8 1·4	8 8·4	9 3·4
9·0	5 4·8	6 0·0	6 7·2	7 2·4	7 9·6	8 4·8	9 0·0	9 7·2
9·3	5 7·0	6 2·4	6 9·8	7 5·3	8 0·7	8 8·2	9 3·6	9 11·0
9·6	5 9·1	6 4·8	7 0·5	7 8·2	8 3·8	8 11·5	9 7·2	10 2·9
9·9	5 11·3	6 7·2	7 3·1	7 11·0	8 7·0	9 2·9	9 10·8	10 6·7
10·2	6 1·4	6 9·6	7 5·8	8 1·9	8 10·1	9 6·2	10 2·4	10 10·6
10·5	6 3·6	7 0·0	7 8·4	8 4·8	9 1·2	9 9·6	10 6·0	11 2·4
10·8	6 5·8	7 2·4	7 11·0	8 7·7	9 4·3	10 1·0	10 9·6	11 6·2
11·1	6 7·9	7 4·8	8 1·7	8 10·6	9 7·4	10 4·3	11 1·2	11 10·1
11·4	6 10·1	7 7·2	8 4·3	9 1·4	9 10·6	10 7·7	11 4·8	12 1·9
11·7	7 0·2	7 9·6	8 7·0	9 4·3	10 1·7	10 11·0	11 8·4	12 5·8
12·0	7 2·4	8 0·0	8 9·6	9 7·2	10 4·8	11 2·4	12 0·0	12 9·6

EXTRACTS FROM BOARD OF TRADE REGULATIONS.

THE expression "PRESSURE" means the difference of electrical potential between any two conductors through which a supply of energy is given, or between any part of either conductor and the earth; pressure, on any alternating current system, being taken to be the equivalent of pressure on a continuous current system when it produces an equal heating effect if applied to the ends of a thin stretched wire or carbon filament; and

(*a*). Where the conditions of the supply are such that the pressure cannot at any time exceed 300 volts, if continuous, or the equivalent of 150 volts, if alternating, the supply shall be deemed a low pressure supply;

(*b*). Where the conditions of the supply are such that the pressure may exceed the limits of a low pressure supply, but cannot exceed 3000 volts, or the equivalent of 3000 volts, whether continuous or alternating, the supply shall be deemed a high pressure supply.

(*c*). Where the conditions of the supply are such that the pressure may on either system exceed 3000 volts, or the equivalent of 3000 volts, the supply shall be deemed an extra high pressure supply.

Mains, service lines, and other conductors and apparatus are referred to as low pressure, high pressure, and extra high pressure mains, &c., according to the conditions of the supply delivered through the same or particular portions thereof.

PRECAUTIONS AGAINST CONTACT (19).—In every case where any transforming apparatus is installed on the consumer's premises as described in the preceding regulation, some means or apparatus approved by the Board of Trade shall be provided which shall render it impossible that the low pressure service lines and consumer's wires shall be at any time charged to a dangerous difference of potential from the earth, owing to any accidental contact with, or leakage from, the high pressure system either within or without the transformer.

ELECTRIC METERS.

56. METER TO BE CERTIFIED.—A meter shall be considered to be duly certified under the provisions of this Order, if it be certified by an electric inspector appointed under this Order; to be of some construction and pattern, and to have been fixed, and to have been connected with the service lines in some manner approved of by the Board of Trade, and to be a correct meter; and every such meter is in this Order referred to as a "certified meter": Provided that where any alteration is made in any certified meter, or where any such meter is unfixed or disconnected

from the service lines, such meter shall cease to be a certified meter, unless and until it be again certified as a certified meter under the provisions of this Order.

58. UNDERTAKERS TO SUPPLY METERS IF REQUIRED TO DO SO.—Where the value of the supply is under this Order required to be ascertained by means of an appropriate meter, the Undertakers shall, if required so to do by the consumer, supply him with an appropriate meter, and shall, if required so to do, fix the same upon the premises of the consumer and connect the service lines therewith, and procure such meter to be duly certified under the provisions of this Order, and for such purposes may authorise and empower any officer or person to enter upon such premises and execute all necessary works, and to do all necessary acts ; provided that previously to supplying any such meter the Undertakers may require such consumer to pay to them a reasonable sum in respect of the price of such meter, or to give security therefor, or (if he desires to hire such meter) may require him to enter into an agreement for the hire of such meter as hereinafter provided.

ELECTRICAL MEASUREMENTS.

The Paris Congress Units (1884) are now universally adopted and consist as follows:

Electromotive Force, and Potential (E).—The Volt. *The legal volt is* ·926 *of the E.M.F. of a Daniell's cell, which for rough purposes may be taken as a volt.*

The legal volt is about 1·3 per cent. greater than the B. A. volt, and the true volt is about ¼ per cent. greater than the legal volt.

Resistance (R).—The Ohm. The legal ohm is now represented by the resistance of a column of mercury of a square millimetre in section at the temperature of zero centigrade 1·062 metres long.

Current (C).—The Ampere. This is the strength of current sent through a wire having the resistance of 1 ohm at the E.M.F. of 1 volt.

Quantity (Q).—The Coulomb. It is the quantity of electricity given by an ampere in a second. One coulomb decomposes ·00144 grain of water.

Heat or Work (W).—The Joule, or Volt-Coulomb, is the work done by 1 coulomb in 1 ohm in one second. The work done by any current per second is obtained in ergs by the product of the current into the electromotive force producing it, $W = C\,E$ or $W = C^2R$. The Erg is the C. G. S. unit of work.

Power (P).—The Watt, $1 \div 746$ of a horse-power, employed in doing 1 joule of work in 1 second.

HP, or the Horse-power, is found by dividing C E by 746, thus

$$\frac{C\,E}{746} \text{ or } \frac{C^2R}{746} = \text{HP}.$$

See also explanation of technical terms.

English and French Measures.

Millimetre = 0·039 inch.	1 mill. = 0·0254 millimetre.
Centimetre = 0·393 inch.	1 inch = 2·5399 centimetres.
Decimetre = 3·937 inches.	1 foot = 3·3480 decimetres.
Metre = 39·37 inches.	1 yard = 0·91439 metre.
Kilometre = 0·62 mile.	1 mile = 1610 metres.

Square millimetre = 0·0016 square inch.
Square metre = 10·76 square feet.
Cubic metre = 35·32 cubic feet or 1·31 cubic yard.
Gramme = 15·432 grains. Kilogramme = 2·2 pounds.
Litre = 0·22 gallon.

Thermometric Scales.

	Equivalent temperatures.	Freezing Points.	Boiling Points.
Fahrenheit . . .	41°	32°	212°.
Centigrade . . .	5°	0°	100°.
Reaumur . . .	4°	0°	80°.

ELECTRICAL TABLE OF THE BIRMINGHAM WIRE GAUGE FOR PURE COPPER.

B.W.G. No.	Diameter in Inches.	Diameter in Millimetres.	Area in Square Inches.	Circumference in Inches.	Pounds per Mile.	Feet per Pound.	Feet per Ohm.	Ohms per 1000 Feet.
1	·3	7·62	·070686	·94248	1444·0087	3·662	8706·843	·1148
2	·284	7·21	·063347	·89221	1291·8699	4·0988	7803·51	·1282
3	·259	6·58	·052685	·81367	1074·5697	4·9262	6490·09	·1540
4	·238	6·04	·044488	·74770	907·3683	5·850	5580·01	·17007
5	·22	5·59	·038013	·69115	773·045	6 83	4681·1	·2136
6	·203	5·16	·032365	·63774	657·205	8·02	3985·7	·2509
7	·180	4·57	·025447	·56549	517 493	10·20	3134·8	·3190
8	·165	4·19	·021382	·51836	434·861	12·14	2633·7	·3797
9	·148	3·76	·017203	·46495	349·853	15·10	2119 9	·4719
10	·134	3·40	·014103	·42097	286·651	18·44	1737·0	·5757
11	·120	3·05	·011309	·37699	229·997	22·95	1392·9	·7179
12	·109	2·77	·009331	·34243	189·763	27·82	1149·4	·8700
13	·095	2·41	·007088	·29845	144·144	36·63	873·1	1·1454
14	·083	2·11	·005411	·26075	110·035	47·98	665·3	1·503
15	·072	1·83	·004071	·22619	82·790	63·77	501·5	1·9941
16	·065	1·65	·003318	·20420	67·478	78·25	408·7	2·4466
17	·058	1·47	·002642	·18221	51·3163	102·89	310·8	3·2176
18	·049	1·24	·001886	·15394	38·3486	137·68	232·3	4·3052
19	·c42	1·07	·001385	·13195	28·1741	187·40	170·6	5·8599
20	·035	·89	·000962	·10995	19·5677	269·83	118·5	8·4381
21	·032	·81	·000804	·10053	16·3574	322·79	99·1	10·c94
22	·028	·71	·000616	·08796	12·5242	421·58	75·8	13·185
23	·025	·63	·000491	·07854	9·9845	528·82	60·5	16·539
24	·022	·55	·000380	·06911	7·7299	683·06	46·8	21·357

ELECTRICAL RESISTANCE OF COPPER WIRE IN FRENCH MEASUREMENTS.

B.W.G No.	Diameter in Millimetres	Area in Millimetres.	Circumference in Millimetres.	Metres per Kilogramme.	Kilogrammes per Metre.	Resistance in Ohms per Kilogramme.	Resistance in Ohms per Metre.	Kilogrammes per Ohm.	Metres per Ohm.
1	7.62	45.6	23.9	1m95	0k514	0.00073515	0.000377	1360	2652
2	7.21	40.8	22.6	2.78	0.360	0.00116760	0.000420	860	2379
3	6.58	34	20.7	3.33	0.300	0.00168165	0.000505	595	1980
4	6 04	28.7	19	3.95	0.253	0.00232260	0.000588	430	1700
5	5.59	24.5	17.6	4.61	0.217	0.00322700	0.000700	310	1430
6	5.16	21	16.2	5.43	0.184	0.00452319	0.000833	220	1200
7	4.57	16.4	14.3	6.90	0.145	0.00731400	0.00106	137	945
8	4.19	13.8	13.1	8.20	0.122	0.01025000	0.00125	98	802
9	3 76	11.1	11.8	10.20	0.098	0.01581000	0.00155	63	646
10	3.40	9.1	10.7	12.50	0.080	0.0237500	0.00190	42.20	527
11	3.05	7.3	9.6	13.50	0.074	0.0318600	0.00236	31.40	424
12	2.77	6	8.7	18.87	0.053	0.0539682	0.00286	18.60	350
13	2.41	4.6	7.6	24.80	0.0403	0.0932480	0.00376	10.70	266
14	2.11	3.5	6.63	32.40	0.0309	0.160380	0.00495	6.26	202
15	1.83	2 63	5.75	45.10	0.0232	0.294954	0.00654	3.40	153
16	1.65	2.14	5 18	52.90	0.0189	0.430077	0.00813	2.30	123
17	1.47	1.70	4.62	69.40	0.0144	0.73564	0.0106	1.35	94.5
18	1.24	1.21	3.90	94.30	0.0106	1.33906	0.0142	0.75	70.4
19	1.07	0.9	3.36	135.10	0.0074	2.60743	0.0193	0.38	51.9
20	0.89	0.62	2 80	181.8	0.0055	5.05404	0.0278	0.20	36
21	0.81	0.51	2.54	212.8	0.0047	7.04168	0.0331	0.14	30.2
22	0.71	0 39	2.23	285.7	0.0035	12.37081	0.0433	0.08	23.1
23	0 63	0.31	1.98	364	0 0028	19.6924	0.0541	0.05	18.5
24	0.55	0.24	1.73	465	0.00215	32.5500	0.0700	0-03	14.3

TABLE SHOWING HOURS OF LIGHTING THROUGHOUT A YEAR OF 8,760 HOURS.

Daily Lighting.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total per Annum.
From sundown to 8 p.m.	125	89	67	36	6	—	—	21	54	87	117	140	742
„ 9 „	156	117	98	66	37	20	25	52	84	118	147	171	1,091
„ 10 „	187	145	129	96	68	50	56	83	114	149	177	202	1,456
„ 11 „	218	173	160	126	99	80	87	114	144	180	207	233	1,821
„ midnight	249	201	191	156	130	110	118	145	174	211	237	264	2,186
„ 2 a.m.	311	257	253	216	192	170	180	207	234	273	297	326	2,916
„ 4 „	373	313	315	276	254	230	242	269	294	335	357	388	3,646
From 4 a.m to sunrise	125	92	69	32	3	—	—	24	51	75	103	154	728
5 „ „	94	64	38	2	—	—	—	—	21	44	73	123	459
6 „ „	63	36	7	—	—	—	—	—	—	13	43	63	245

EXPLANATION OF TECHNICAL TERMS.

Accumulator.—Another name for secondary batteries.

Alternating Current.—An electric current, the direction of which in the conductor is reversed usually many times in a second.

Alternate Current Dynamo.—Produces currents which are alternately positive and negative.

Amalgamation.—Zinc is protected from local action by having its surface coated with mercury.

Ampere.—The unit of current. A volt divided by an ohm. (See Electrical Measurements, page 199.)

Ampere hour.—A current of one ampere strength for one hour.

Ampere meter.—An instrument used for measuring strength of current in amperes.

Anode.—The positive electrode or pole of a decomposing cell, the wire or plate connected to the copper or other negative element of a battery. In electro-plating, it is usually the soluble pole of the metal to be deposited. (See Cathode.)

Arc.—The air space in which the electric-light forms.

Armature.—The keeper of a magnet; the part which closes the magnetic lines of the field-magnet, or in dynamos the rotary bobbins.

B. A.—British Association.

Battery.—A combination of two or more voltaic cells or accumulators coupled together.

Block Station.—A central-station for the supply of continuous buildings.

Board of Trade Unit.—One thousand watt hours; equals work done by 10 amperes at 100 volts in an hour, or 1·35 H.P. working for one hour.

Bobbin.—A coil of wire, or a number of such coils.

Bridge (Wheatstone's).—An apparatus for measuring resistances by balancing the unknown resistance against one known and capable of adjustment.

Brush.—The brushes of a dynamo machine are conductors, usually flexible, pressed in contact with the revolving part of the machine, in order to convey current between it and an external circuit.

B. W. G.—Birmingham wire gauge.

Cables.—Twisted cords or ropes of copper wire covered with insulating material.

Candle Power.—Term used to denote the amount of light as compared with a standard sperm candle, which is a spermaceti candle, burning at the rate of 2 grains per minute. Abbreviated C.P.

Capacity (K).—The power of a surface to hold electricity as "static charge." Its unit is the Farad. A coulomb divided by a volt.

The Capacity of a conductor is measured by the quantity of electricity required to raise the pressure one volt.

Carboid.—A preparation of carbon used for brushes of dynamos.

Carbon Filament.—The thread of carbon used in a glow-lamp, made of paper, silk, or some vegetable fibre previously reduced to carbon.

Carbons.—The electrodes of arc-lamps ; the negative plates of a battery.

Carcel Lamp.—The French standard, equal to 9·4 candles.

Cathode.—The negative pole of a battery ; the wire or plate connected with the zinc or positive element of the battery. The object on which a metallic deposit is to be formed. (See Anode.)

Ceiling Rose.—A connection used for suspending an incandescent lamp.

Cell.—Each separate vessel in which a chemical action occurs, by which electricity is capable of being developed.

Centigrade.—See Thermometer Scales, p. 200.

Centimetre.—The hundredth part of a metre, 0·393 inches.

Central-station.—A building containing plant for supplying electricity to the public.

C. G. S.—The centimetre-gramme-second system.

Charge.—(*a*) The quantity of electricity on the surface of a conductor. (*b*) The quantity of electricity which flows across a section of the circuit joining the terminals of an accumulator during its complete discharge.

Circuit Breaker or Contact Breaker.—The electric-lighting equivalent for a gas tap.

Circuit, Closed.—A continuous path for the electric current.

Circuit, Conductive.—The wires which form the path for the passage of the current.

Coefficient of Self-Induction.—The value of the electromotive force produced in a coil when a current flowing through it changes at the rate of one ampere per second.

Collector.—Any device used to make electrical contact with a moving body.

Commutator.—A circuit changer or switch. The collector of currents on a dynamo.

Compound Winding.—A method of keeping the voltage at the terminals of a dynamo constant when the load varies.

Concentric Mains.—Conductors enclosed one in the other.

Condenser.—Two sets of conductors near to but insulated from each other.

Conductivity.—Is the reciprocal to resistance, and applies to that property of any substance whereby the passage of electricity through it is effected with the least opposition.

Conductors.—Substances which most freely permit electricity to pass.

Connections.—Wires, etc., completing the circuit between different apparatus.

Contact.—An actual touching or bringing together of the metals composing two conductors.

Continuous Current.—An electric current whose direction of flow remains the same.

Converter.—See Secondary Generator.

Coulomb (Q).—The Unit of quantity, that which passes in one second with a current of one ampere.

Cubic Metre.—35·32 cubic feet, or 1·31 cubic yards.

Current (C).—The Unit is the Ampere. The supposed flow or passage of electricity in the direction from + to —, or positive to negative.

Current, Reverse.—A current in the opposite direction to the normal current.

Cut-out.—An instrument placed in the circuit which will open it automatically, either mechanically or by melting of a fuse.

Decimetre.—The tenth part of a metre—3·93 inches.

Deflection.—The angle or number of degrees at which the needle of a galvanometer stands when a current is passing through its coils.

Detector.—The name given to a galvanometer of portable type, used for testing the continuity of circuits.

Diamagnetic.—The property of substances which offer more resistance to the passage of magnetic lines of force than air.

Diaphragm.—A porous division between two liquids through which electric current passes.

Dielectric.—The substance between the plates of a condenser which opposes the passage of electricity.

Differentially-Wound Dynamo-Machine.—A compound-wound machine in which currents flow in opposite directions in the coils on the field magnets.

Direct Current Dynamo.—An electric generator producing currents passing in one direction.

Disruptive Discharge.—A sudden discharge taking place across or through a non-conductor or dielectric.

Distributing Boards.—Large blocks of wood or slate, upon which are mounted the various switches, fuses, etc., connected with main or branch wires.

Double Break Switch.—A switch that opens or breaks the circuit in two places at the same time.

Double Pole Switch.—A switch mounted so that the circuit is broken at the same time in both conductors.

Duplex Cut-out.—An instrument which enables a spare fuse to be immediately substituted for that melted.

Duty.—A term used to denote the economy of any dynamo or motor.

Dynamo.—A name given to machines which produce electricity for commercial purposes.

Dynamometer.—(1) An instrument for ascertaining the horse-power absorbed by any machine. (2) *Electro-dynamometer.*—An instrument used for measuring current.

Dynamotor.—See Motor Transformer.

Dyne.—The Unit of force which gives a velocity of one centimetre per second to one gramme mass after acting for one second.

Earth.—A term for the return circuit, which for economy is formed through the earth in telegraph work. A return conductor common to many circuits is sometimes called "earth."

Eddy Currents.—See Foucault Currents.

Electricity.—The true nature of electricity has not yet been determined.

Electrocution.—A recently coined word which signifies capital punishment by electricity.

Electrodes.—A term for the poles or plates leading the current into and out of a cell.

Electroliers.—Pendants or hanging fittings for electric lamps.

Electrolysis.—The act of decomposition by the electric current.

Electrolyte.—The liquid in a cell.

Electrometer.—An instrument for measuring electric potential.

Electro-Magnet.—A magnet whose magnetic property is obtained from a current of electricity passed through a circuit round the magnet.

Electromotive Force (*E. M. F.*) (E).—The electric force tending to produce electric current. The Unit is the Volt.

Erg.—The C. G. S. Unit of energy. The work of moving a body through one centimetre against the force of a dyne.

Exciter.—Is a generator used for producing the current necessary for magnetising the field magnets of another dynamo-machine.

Extra Current.—The induced current of higher E. M. F. which appears in a wire having self-induction when the current is broken.

Fahrenheit.—See Thermometer Scales, p. 200.

Farad.—The Unit of capacity: a coulomb divided by a volt.

Feeder.—A wire distributing current to the main conductors.

Field of Force.—The space around and between the poles of a magnet.

Field Magnet Coils.—The insulated copper wire coils round the field magnets.

Field Magnet Cores.—The iron centres or cores in the field magnets on which the coils are wound.

Field Magnets.—In a dynamo the magnets between which the armature revolves.

Filament.—That part of an incandescent lamp that gives out the light.

Five Wire System.—A method of distributing moderately high pressure continuous currents of electric energy from central stations over a larger area than would otherwise be economically possible with the ordinary parallel system using two wires.

Foot-Pound.—The British Unit of work, or 1 lb. raised 1 foot high.

Foucault Currents.—Currents produced in the metallic masses of pole-pieces and armatures by their motion in a magnetic field, or by variation in the surrounding currents.

Frame of a Machine. The metal work supporting the working parts.

Frequency.—The number of alternations of a current per second.

Fuse.—A metal wire or strip inserted in a circuit, and designed to melt (and so break the circuit) on the passage of an excessive current. (See Mica-foil.)

Galvanometer.—An instrument for measuring current.

Generator.—Another term for a dynamo.

Glow Lamp.—See Incandescent Lamp.

Governor.—An apparatus for controlling the speed of any motor.

Hectowatt.—One hundred watts.

High Pressure or High Tension.—An electromotive force of over 300 volts in a continuous current or 150 volts in an alternating current.

Horse Power (HP.)—indicated HP.—The Unit is 33,000 lbs. lifted 1 foot high per minute. The nominal HP. of any motor is generally fixed considerably less than the indicated. An electrical HP. equals 746 watts.

$$\text{Ind. HP. of any engine} = \frac{2\,A\,P\,R\,S}{33{,}000}$$

A = Area of piston in square inches.
P = Average pressure of steam in lbs. per square inch.
R = Number of revolutions per minute.
S = Length of stroke in feet (if in inches × 33,000 by 12).

The French "force de cheval" represents 32,560 foot-pounds.

Horse Power of Water.—Indian Government rule, 15 cube feet per second falling through 1 foot = 1 HP.

Hysteresis.—Molecular friction of a magnetic substance resulting in loss of energy, as in a transformer.

Incandescent Lamp.—An exhausted glass bulb containing a filament of carbon heated to incandescence.

Indicator Diagram.—The drawing produced by an instrument which is fixed to the cylinder of a steam engine for the purpose of ascertaining its duty.

Induction.—The name given to effects of the same general character as the cause, at a distance. A current rising or falling in a wire induces currents in other conductors parallel to it. A static charge *induces* charges elsewhere. A magnet *induces* magnetism in neighbouring iron.

Inertia.—The resistance to change of state of rest or motion.

Inspection Boxes.—Manholes which can be opened to inspect electric mains.

Installation.—The plant or materials used to produce or utilise electric light or power.

Insulators.—Bodies possessing high electrical resistance; cables and wires are covered with an insulating material, but all insulating substances allow some electricity to pass.

Intensity.—The old term for current; now sometimes employed to denote current per unit of area of cross section.

Intermittent Current.—An interrupted current whose direction is continuous.

Internal Resistance.—The electrical resistance due to the construction of the battery or generator.

Joule (W).—The Unit of heat or work; it has also been applied to the mechanical equivalent of heat, 722 foot-pounds. (See Work.)

Kilowatt.—One thousand watts $1\frac{1}{3}$ HP. (See Board of Trade Unit.)

Knot.—The geographical, or nautical mile.

Leads.—Terms usually applied to copper conductors.

Life of Lamps.—The duration of the filament.

Load-factor.—See page 190.

Local Action.—Local waste of energy in a dynamo or battery.

Low Pressure.—See High Pressure.

Magnetic Field.—See Field of Force.

Magnetic Lines of Force.—Curves showing the direction of force in the Field of Force of a magnet. (See Field of Force.)

Magnetism.—A condition which can be highly developed in iron and steel, by electric action or otherwise.

Mains.—The principal conductors.

Make and Break.—On closing a switch contact is made; on opening it, contact is broken.

Manholes.—See Inspection Boxes.

Measurement.—See Units.

Megohm.—A million ohms; the prefix meg signifies a million.

Metre.—The French standard of length = 3·28 feet.

Mica-foil.—The fusible portion of a Hedges cut-out.

Milliampere.—The thousandth part of an ampere.

Millimetre.—The thousandth part of a metre—0·039 inch.

Motor Transformer.—A dynamo driven by a motor.

Motors.—Machines for developing power by means of electrical energy.

Multiphase.—A system employing alternating currents which do not synchronise.

Multiple Arc.—Galvanic cells or dynamos connected in parallel, or lamps so arranged that each furnishes a separate path for the current.

Negative.—In a machine the wire returning from the lamp. In a galvanic battery the copper, carbon, or platinum plate. Sign —.

Nigger.—An American term used to denote an electrical fault.

Non-Conductor.—See "Insulators."

Ohm.—The Unit of resistance. A volt divided by an ampere.

Ohm's Laws—Laws, investigated by Ohm, regulating electrical current magnitudes. Calling the current C, electromotive force E, and resistance R: the expression is

Current	E.M.F.	Resistance.
$C = \frac{E}{R}$, amps.	$E = C \times R$, volts.	$R = \frac{E}{C}$, ohms.

(See Electrical Measurements.)

Oil Insulators.—Stoneware or glass supports for wires with grooves to contain oil.

Osmose.—The process of diffusion of liquids through a porous division.

Paraffine.—An insulating substance much used in telegraph work.

Parallel.—The plan of connecting generators or transformers or lamps so that the current divides into parallel paths.

Phase Indicator.—Apparatus used to show when alternating dynamos are in synchronism.

Plummer Block.—The bearing on which a shaft revolves.

Polarisation.—The retardation of current in a battery due to an opposing E.M.F.

Polarity.—The distinct features of the two separate poles of a magnet.

Poles.—The two ends of a magnet. The junction of a dynamo or voltaic battery with the external parts of the circuit.

Positive.—In a machine the wire proceeding to the lamp. In a battery the zinc plate. Sign +.

Potential.—A word used to indicate a condition for work. Difference of potential is a difference of electrical condition. Potential of a battery means its E.M.F.

Power (P).—The rate of doing work. When a current of one ampere passes through one ohm, a unit of power, called a Watt, is employed.

Pressure of Electricity.—The electromotive force between it and the earth. The pressure of electricity on the earth is taken at zero.

Primary Cell.—A cell in which the plates and liquid or liquids are renewed when exhausted.

Primary Coil.—The circuit in a transformer which is connected to the generator.

Quantity (Q).—The Unit is the Coulomb.

Quick-Break Switch.—A switch constructed with a powerful spring acting on the handle so that the spring forces the switch "off" with a snap.

Reactive Coil.—A coil of wire wound round a magnetisable core placed in a circuit of an alternating system, in order to control the amount of current passing through the system.

Receiver.—The part of a telephone which is held to the ear and converts the electric pulsations into mechanical vibrations.

Reducing Switch.—The term applied to a switch containing a small resistance capable of being gradually brought into the circuit.

Relay.—An electro-magnet which, receiving its current from a distance, closes the circuit of a local battery so as to produce the required effect of strength.

Resistance (R).—The opposition presented by the circuit to the development of the current. The Unit of resistance is the Ohm.

Resistances, Artificial.—Substances (usually coils of iron wire or strip) inserted in a circuit so as to oppose the passage of the current and absorb power, usually used for regulating purposes.

Return Current.—The current in the wire leading to the machine.

Rheostat.—An instrument for inserting resistances. A variable artificial resistance employed for measuring unknown resistances.

Rigger.—The pulley or wheel by which power is transmitted.

Rotary Current System.—One employing more than one alternating current, with a difference of phase between them. See p. 165.

Secondary Battery or Cell.—Wrongly termed an accumulator; is an appliance for storing energy in such a form that it shall be available for the reproduction of electric currents.

Secondary Coil.—The circuit in a transformer in which a current is induced.

Secondary Generator.—A transformer of a current of high potential into a current of less E.M F., or *vice-versâ.*

Self-Induction.—The E.M.F. produced by a rising or falling current ***in its own conductor.***

Series.—The plan of connecting lamps so that the current passes through one after the other.

Series-Wound Dynamo Machine.—A machine in which the coils on the field magnets are placed in series with the external circuit.

Short Circuit.—A path of comparatively no appreciable resistance.

Shunt.—A coil of wire arranged to take a certain proportion of any current.

Shunt-wound Dynamo Machine.—A machine in which the coils on the field magnets are placed parallel with the external circuit.

Single Break Switch.—A switch that opens or breaks the circuit in one place only.

Solenoids.—Helices of wire which act like magnets.

Specific Resistance.—The resistance of a conductor one centimetre long and one square centimetre cross section is called the specific resistance of the substance of which the conductor is made.

Spectrum.—The elongated figure of the prismatic colours.

Steam Dynamo.—A dynamo coupled directly to a steam engine.

Storage Cell.—See Secondary Battery.

Switch.—An apparatus for changing one circuit on to another, or causing a break.

Switch Board.—See Distributing Board.

Tension.—An expression used for electromotive force.

Terminals.—In an open circuit the ends of the conductors.

Thermopile.—An arrangement of metallic conductors which when heated generate electricity.

Three-wire System.—A method of distributing electric energy in a similar way to that described under "Five-wire System."

Torque.—Term used to express the strain on a shaft subject to twist round its axis.

Transformer.—See Secondary Generator.

Transmitter.—The part of a telephone which is spoken into, and which converts the mechanical vibrations of sound into electric pulsations.

Trunk Wires.—See Mains.

Unit of Supply.—A complete set of plant employed to generate electricity.

Units.—The various bases of any system of measurement.

Volt.—The Unit of electromotive force and potential. An ampere multiplied by an ohm. (See Electrical Measurements.)

Voltage.—A term used to express electromotive force.

Voltameter.—An apparatus for measuring the current by its chemical action.

Voltmeter.—An instrument for measuring E.M.F.

Wall Plug.—The movable connection of the insulated wires of a portable lamp by which it can be fixed into any socket.

Watt.—The Unit of power. A volt-ampere. The electrical horse-power is equal to 746 watts. The "force de cheval," or horse-power in use abroad, is defined as 75 kilogrammetres, and is, therefore, 736 watts.

Watt-Hour.—The work done by the power of one watt in one hour.

Wood Casing.—Used for the protection of insulated electric wires or cables.

Work (W).—Is a volt multiplied by a coulomb, or amp.^{2} × sec. × ohm, or amp. × sec. × volt. The Unit is the Joule.

Yoke.—Is a term applied to the apparently neutral mass of iron which connects the poles of a horse-shoe magnet, and is capable of being removed.

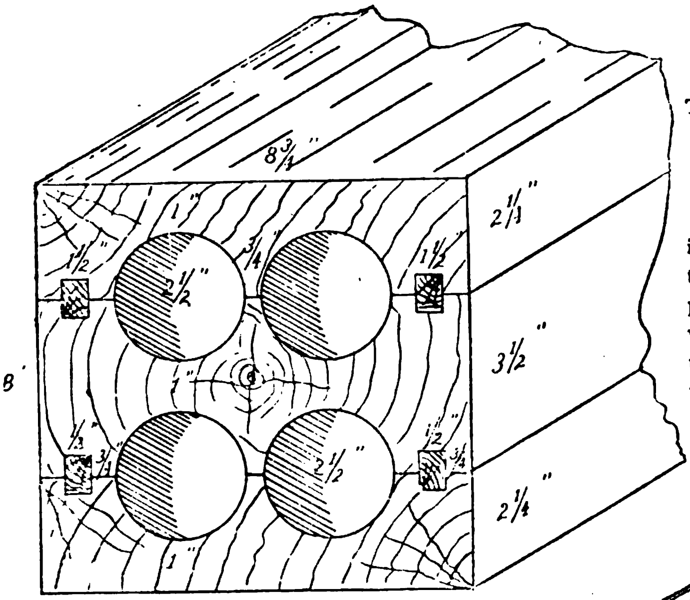
LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.

MEMORANDA.

THE "MACDONALD"

PATENT

Subway Electrical Conduit.



TESTIMONIAL FROM

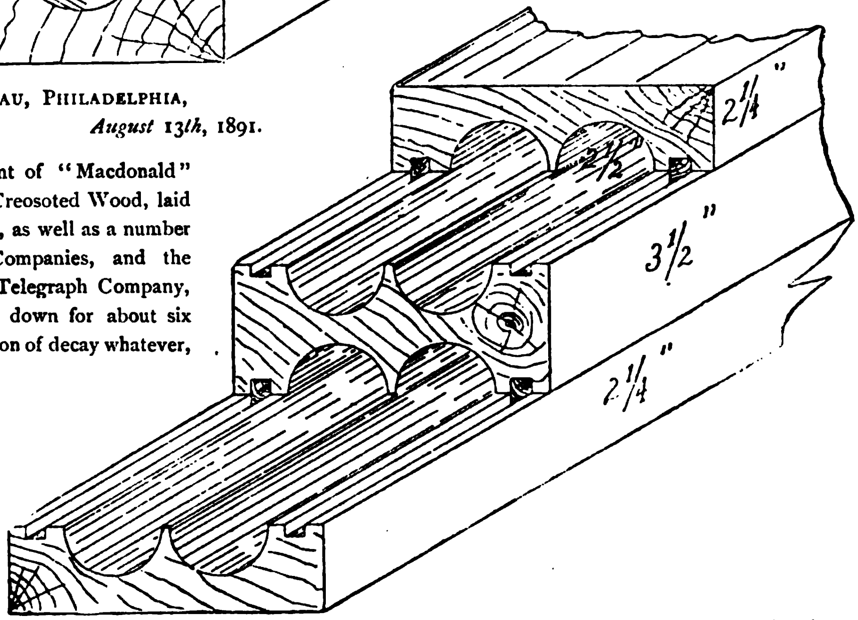
THE EDISON ELECTRIC ILLUMINATING CO.,
PATERSON, NEW JERSEY,
August 10th, 1891.

We have had the "Macdonald" system in use for Arc Lighting Circuits the past three years, using a current of 2,500 volts potential, and have never had any trouble with them; and were we to extend our underground lines, would undoubtedly use the same system.

(Signed) WM. M. BROCK,
General Manager.

ELECTRICAL BUREAU, PHILADELPHIA,
August 13th, 1891.

There is a large amount of "Macdonald" Patent Conduit, made of Creosoted Wood, laid in this City by this Bureau, as well as a number of the Electric Light Companies, and the American Telephone and Telegraph Company, some of which has been down for about six years and shows no indication of decay whatever, and from appearances I would judge it to last a great number of years. It is easy of access for Cables, and the Cables are drawn-through it without any strain or chafing. It is simple in construction, and can be laid rapidly, and additions can be made to it from time to time, without any trouble, by simply opening the sheets and building it up.



(Signed) D. R. WALKER, *Chief of Bureau.*

The Conduit is made of Creosoted Timber, the Sections being in 14-feet lengths, and the Ducts 2½-inches in diameter, but larger or smaller sizes can be made, if desired.

100 MILES HAS BEEN LAID SUCCESSFULLY IN THE UNITED STATES.

FOR FURTHER PARTICULARS APPLY TO

EDWARD SPENCER & Co., FENCHURCH STREET, E.C.

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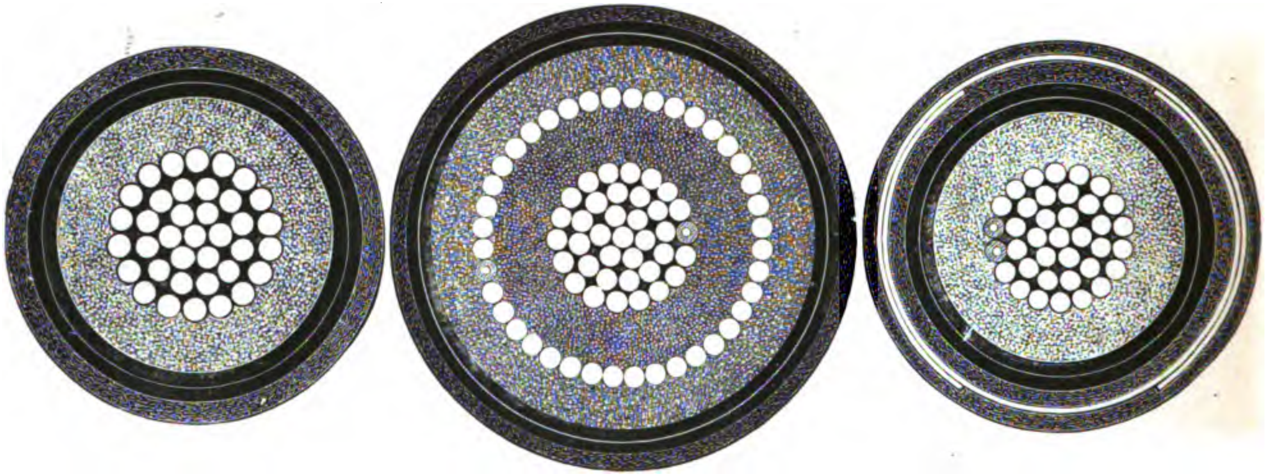
Gold Medal Awarded Paris Electrical Exhibition, 1887.

FELTEN AND GUILLEAUME,

Carlswerk, Mulheim-on-Rhine, Germany,

Manufacturers of ELECTRICAL CONDUCTORS.

Gutta-Percha and India-Rubber covered Wires and Cables;
Lead covered Cables for Electric Light purposes;
Cables for Central Station Lighting.



In the following Central Light Installations, FELTEN & GUILLEAUME'S Lead Covered Electric Light Cables are used :—

HAMBURG FREE PORT, BREMEN FREE PORT, LUBECK, HAMBURG, BARMEN, HANOVER, DUSSELDORF, ALTONA, KONIGSBERG, AIX-LA-CHAPELLE, AMSTERDAM, CHRISTIANIA, DIJON, OVIEDO, BURGOS, SEVILLE, PORT OF ODESSA.

Telegraph Wire, Galvanised and Plain (to any specification).
Telephone Wire, Galvanised Patent Cast Steel.
Covered Wires for Telephones. Gutta-Percha and India Rubber Cores.
Lead Covered Cables, for transmitting Power for Telephony and Telegraphy.
Telegraph and Telephone Cables, free from Induction.
Torpedo and Field Telegraph Cables. Cables for Blasting Purposes.
Dynamo Machine Wires.
Iron and Steel Wire for all Purposes, Fencing Wire, Strand, etc.
Wire Ropes for Mining Transmission, Street Tramways, etc.
Copper and Bronze Wire.

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W. F. DENNIS & CO., 11, BILLITER STREET, LONDON, E.C.

N.B.—OUR EXHIBIT AT FRANKFORT IS DESCRIBED IN A SPECIAL PAMPHLET, WHICH WILL BE READILY SENT ON APPLICATION.

HEDGES' ❖ PATENT ❖ CUT-OUTS

AND

FUSIBLE ❖ MICA-FOILS.

For the Protection of Electric Light and Power Circuits from the dangers of Short Circuits and Overheating.

FIG. 1.

FIG. 3.

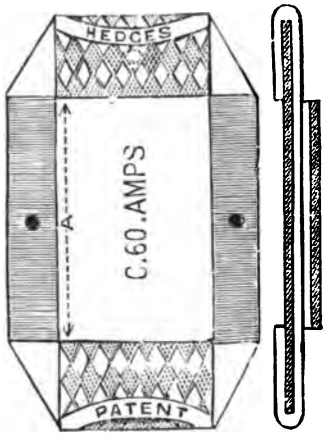

FIG. 2.

FIG. 1 shows the Eyelet-foil made to fit almost any size or make of Cut-Out; it is cheaper than lead or tin wire; the Fuse shown in FIG. 2 is used from 20 to 1000 amperes; FIG. 3 is a Double-pole Form with removable Mica-foil, which is shown inserted.

HEDGES' MICA-FOILS are exclusively employed at the South Kensington Museum, and in many of the public buildings throughout the country. They are recommended and passed by all the Fire Insurance Offices.

Prices and Samples can be obtained from the Licensed Makers,

THE CARBOID OIL-LESS BEARING COMPANY,

Makers of Electric Light Carbon Rods and Carbon Plates, both Cut and Pressed.
Experimental Carbon Work of all descriptions.

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